



ARCHITECTS' AND ACOUSTIC CONSULTANTS' LOW-COST CONSIDERATIONS
FOR IMPROVING CLASSROOM ACOUSTICS IN THE SOUTH AFRICAN CONTEXT.

A Dissertation in Fulfilment of the Requirements of

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Abstract

Literature reports on the negative effects poor classroom acoustics could have on learners' academic performance. South Africa is a mixture of a developing and developed country, therefore there is a need to be cost-conscious due to the possible limited resources available. There is limited research on how to address the above issue of poor acoustics. Thus, a low-cost method to acoustically treat an existing classroom needed to be explored. Architects and acoustic consultants were used as the participants as they are professionals who may be involved in classroom acoustic treatments. The aim of the study was to obtain architects' and acoustic consultants' low-cost considerations to acoustically treat an existing classroom. This aim was achieved through a mixed-method sequential explanatory approach. A qualitative approach involved the participants having to draw out their considerations to acoustically treat an example classroom, while simultaneously participating in a semi-structured interview. The qualitative data were placed into the Sabine reverberation equation for a quantitative approach to calculate the post-acoustic treatment reverberation time. The study found that there are methods to acoustically treat classrooms in a low-cost yet effective way. Prioritising the treatment of reverberation and treating the entire ceiling with Class C acoustic ceiling tiles with a Noise Reduction Coefficient (NRC) of 0.70 seemed to be the most ideal solution. The study concluded that by using the Sabine reverberation equation, one could implement the bare minimum treatment needed in order to achieve an appropriate reverberation time. This is important for South Africa, where resources may be limited. Through this study, a basic acoustic treatment guideline was developed, however, there is a need for change in policy at a government level to ensure that all classrooms are conducive to learning and teaching.

Keywords: classroom acoustics, architect, acoustic consultant, low-cost solutions

Declaration

I, Chantal J. Kassuto, declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Masters in Audiology at the University of the Witwatersrand, Johannesburg. It has never been submitted for any degree or examination at any other university. All sources which have been used, made reference to, or quoted have been indicated and acknowledged.

A handwritten signature in black ink, appearing to read 'Chantal', is written over a horizontal line.

Signature of Chantal Jacquie Kassuto

03 July 2019, in Johannesburg.

This dissertation is dedicated to the loving memory of (Z'LT)

Lyn Nathan (Granny) and Ya'akov Kassuto (Sabba)

Two inspiring individuals that had a great influence in my life.

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List of Abbreviations

ANC – African National Congress

ANOVA – Analysis of Variance

ANSI – American National Standards Institute

ASA – Association Society of America

ASHA – American Speech-Language-Hearing Association

BSA – British Society of Audiology

dB - decibel

dBA – A-weighted decibel

ICT – Information Communication Technology

NCAC – National Council of Acoustical Consultants

NRC – Noise Reduction Coefficient

PEI – Photo/Picture Elicitation Interviewing

RT – Reverberation Time

SAFE – Sanitation Appropriate for Education

SAIA – South African Institute of Architects

SANS – South African National Standard

STI – Speech Transmission Index

WHO – World Health Organisation

Chapter 1: Introduction

1.1. Statement of the Problem and Rationale for the Study

“Education is the most powerful weapon which you can use to change the world” –

Nelson Mandela (Soudien, 2005, p134).

Nelson Mandela placed major emphasis on the importance of education, by empowering our youth with knowledge and skills to make a positive change to South Africa. Therefore, access to education is an important topic to discuss. The environment in the classroom has a major influence on the access to education to which the learners are exposed. A learning environment in the classroom can be influenced either positively or negatively by the adequacy of the acoustics. Several studies have been conducted focussing on the effects of classroom acoustics on learners’ academic performance in the classroom and how acoustics influences learners’ access to education. Literature illustrates the negative effects of inadequate classroom acoustics and noise levels in classrooms on speech perception, language processing abilities, academic performance, speech intelligibility, and the wellbeing of children in school (ASHA, 2015; Crandell & Smaldino, 2000; Dockrell & Shield, 2004; Dockrell & Shield, 2006; Erler, Garstecki, Nelson, & Smaldino, 2008; Klatte, Lachmann, Meis, 2010; Yang & Bradley, 2009).

The literature indicates that poor classroom acoustics can create a barrier to learning in the classroom. Inadequate classroom acoustics and increased noise levels in the classroom have proven to affect attention, concentration, behaviour, receptivity, literacy abilities, and overall academic achievement (Gumenyuk, Korzyukov, Alho, Escera, & Naatanen, 2004; Klatte, Hellbruck, Deidel, & Leistner, 2010). Poor acoustic conditions have been shown to cause impaired academic performance when learners are expected to undergo intricate listening tasks such as identification, short-term storage, and mental processing of spoken

information (Klatte, et al., 2010, as cited in Kassuto, 2016). Teachers in these classrooms are highly aware of the effects of noise on their learners in the classroom (Kassuto, 2016), however, teachers lack access to information regarding classroom acoustics solutions (Goldberg & Richburg, 2005).

The volumes of research exhibiting the significant negative effects of poor classroom acoustics and increased noise levels have on learners in the classroom are highly concerning; especially since there is very limited research on low-cost and effective methods to improve acoustics in existing classrooms. Research has shown that classrooms in South Africa are not meeting the standards and regulations recommended by the government (Kassuto, 2016; Ramma, 2007). This could be due to limited and constrained resources. Research has also shown that architects, the professionals who may be involved in the design and building of these classrooms, are not familiar with the acoustic recommendations set by the government. According to Ryder (2017), this could be due to the unclear and vague standards and regulations that are provided for professionals to follow. Another major issue in considering acoustics in the classroom at an architectural level is financial budgets that are set by the schools undergoing a project, especially within a South African context where finance is a major limitation (Hollander, & de Andrade, 2013; Ryder, 2017). Financial reasons are a major consideration which often causes acoustics to become an afterthought in the design of classrooms (Ryder, 2017).

As per the aforementioned research, despite the obvious negative effects of poor classroom acoustics and increased noise levels on the learners in the classroom, the acoustics are still not being considered in the building of classrooms (Kassuto, 2016; Ryder, 2017). This portrays a lack of awareness of the significance of having acoustically adequate classrooms, not only from an architectural point of view but at a school level too. Ryder (2017) reported that the architects she interviewed had a change of heart nearing the end of

the research study where, for example, one participant began to express that he would consider acoustics the next time he was approached with such projects due to the importance and impact it could have on the learners' experience in the classroom. Bringing awareness to all professionals that are usually involved in the development of classrooms is vital in the hope of making a change in our classrooms.

There have been many problems related to the possible negative impact of poor classroom acoustics on learners' academic performance, yet limited solutions. Finance, awareness, experience, and knowing one's role as a professional in the field of acoustics all seem to contribute to the success or failure of acoustically treating classrooms (Ryder, 2016). This study is looking at possible low-cost yet effective ways to successfully acoustically treat classrooms by reducing the reverberation time, ambient noise levels, and improving the Speech Transmission Index (STI), and speech intelligibility in an existing classroom. This study included both architects and acoustic consultants in the data collection process, professionals who are highly qualified in the area of acoustics (NCAC, 2018; SAIS, 2014). Therefore it seems that both professions should be involved in the implementation of acoustic treatments into classrooms and this will be further explained in the literature review.

This research is being conducted not only to find low-cost yet effective ways to acoustically treat an example of a classroom but to share awareness of the importance of having acoustically adequate classrooms that allow all learners of all learning capabilities to have ease of access to education. This further highlights the need for acoustically friendly classroom designs which are easy to follow and guides the professionals involved in building classrooms to apply corrective measures and methods to ensure ease of access to learning in the classroom. In South Africa, there seems to be limited and constrained access to resources, that can become challenging when comparing the need to acoustics in a classroom versus other basic needs, for example, sanitation, that are needed within the area (Gibberd, 2007).

This is why this study has focussed on the least amount of costs to obtain the most amount of value in regard to acoustic treatments within existing classrooms. There is the need to ensure that the future children of South Africa are obtaining an education within an environment which supports them, not an environment that creates barriers to their access to education.

Chapter 2: Literature Review

2.1. Education in South Africa: History, Linguistic Diversity, and Infrastructure.

“While some South African schools have excellent infrastructure, others lack basic services such as water and sanitation” (Gibberd, 2007, p.1). Due to the apartheid policies prior to 1994 there have been many school infrastructure backlogs (Gibberd, 2007). The Department of Education has developed a policy and funding plan to attempt to equalize the backlogs and maintain school infrastructures (Gibberd, 2007). This policy includes prioritizing the backlog of basic services such as water and sanitation with the continuation of improving quality of education in all schools infrastructures (Gibberd, 2007).

The balance between public and private resources in the primary and secondary school sector seems to be a highly looked at topic in global policy (Fiske & Helen, 2003). National governments in developing countries usually lack the resources that are tax-generated to fund education on an appropriate level (Fiske & Helen, 2003). When delving into the scholastic system in South Africa, one has to remain realistic in acknowledging the possible limitations of resources in schools across the nation (Spaull, 2012). Although racial segregation seems to have been abolished for around 24 years, there are still differences between private and the public governed school systems and the resources that follow respectively (Spaull, 2012; Van der Berg, 2008). Following apartheid there was major focus on prioritising education for expansion and restructuring. Even though there was a great focus on the political ideas between pre- and post-apartheid governments, many of the nation's schools continued under the structure that was under apartheid (Spaull, 2012). The previously apartheid governed schools that were dysfunctional under apartheid seem to remain dysfunctional today (Spaull, 2012). This is explained by Taylor, Muller, and Vinjevold (2003) and Fleisch (2008) where dysfunctional schools are represented today by the high

grade repetition, dropout rate, severe under performance, and high absenteeism of teachers. According to the Revised Five-Year Strategic Plan (2016), in 2014, 530 589 South African children between the ages of seven and eighteen were not attending any educational institutions. The Rural Education Draft Policy (2017) states that rural schools in South Africa are characterised by teacher shortages, high dropout rates, absenteeism, inadequate resources, and with the above, causes poor educational outcomes. According to Spaul (2012), these factors could be related to the students' socio-economic disadvantage and the impact of ill discipline, inefficient management, and low-cognitive demand, all of which were legacies of apartheid.

The evident differences on achievements in tests and examinations illustrate South Africa's divided past (Van der Berg, 2008). This illustration is further understood by a study conducted by Taylor (2011): South African primary school learners underwent an assessment for research that measured learner performance. The vast majority of the South African primary school learners scored significantly below where they should have been in relation to the syllabus (Taylor, 2011). The national average reached between 30% to 35% on tests of literacy and numeracy (Taylor, 2011). Fleisch (2008) further explains that there are major inequalities in all areas of South Africa and this is specifically true in education. The minority of learners, 25%, are able to perform acceptably on local and international examinations, however, the majority of learners, around 75%, perform extremely poorly on examinations that are local and international (Spaul, 2012; Van der Berg, 2008).

South Africa has an ecology where cultural, linguistic, and political factors influence the social, educational, and general lifestyle of different individuals (Kathard & Pillay, 2008). There are major influences that need to be addressed when evaluating a learner's success at school. To determine these influences, one can use the concept of environmental scanning. Environmental scanning is used both externally and internally to determine the opportunities

or threats with which a certain environment may present (Juneja, n.d.). Environmental scanning is the use of information about relationships within a certain ecology's internal and external environment (Juneja, n.d.). Within a school setting, environmental scanning can be used to determine internal and external factors that may be affecting a learner's experience at school. Environmental scanning relates to the concept of ecological audiology and the main development in this ecology is interaction. Interaction occurs between an individual and different mechanisms in a given environment (Borg, 1998). Ecological audiology is a term that can be used to analyse a certain individual's interaction with the environment and how it may influence the successful or unsuccessful participation within an ecology (Borg, 1998). When applying this theory to a school environment, one can analyse the learners' internal and external environments that may be influencing their overall learning experience at school and in the classroom. The ecological framework provides a holistic view on the learners' abilities to interact and participate within the school environment. This can provide the reader with an understanding of all the different factors that may be influencing a learner's access to education within a school environment. Although this study focussed on acoustics in the classroom, it is important to consider the South African context and what the learners may be experiencing on a contextual level. Spaul (2012, p.10) illustrates this ecology using a Venn diagram for reading regressions and focuses on the large and significant coefficients as depicted in Figure 2.1.

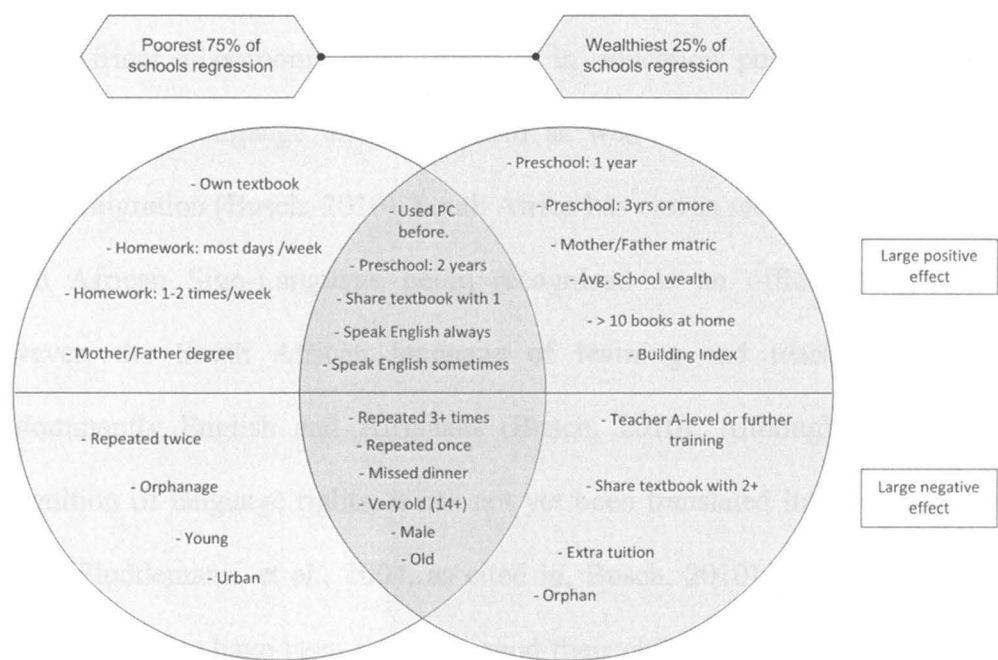


Figure 2.1 Spaul (2012, p.10) illustrates reading regression via a Venn diagram.

Spaul (2012) explains that there are twenty-nine variables that are large and significant, and of the two regressions, there are only eleven commonalities (Figure 2.1). This shows a major discrepancy between the two regressions and how 75% of learners, nationally, are having major difficulties at schools due to their socio-economic background, upbringing, and home environment (Spaul, 2012; Van der Berg, 2008; Case & Yogo, 1999). This regression illustrates how important it is to look at learners holistically and determine why they may not be performing optimally. Availability of resources at home, having educated parents that are able to assist with learning, and having parents that are present, all have major influences on a learner’s ability to succeed academically (Spaul, 2012; Van der Berg, 2008). The poorer schools, in rural and township areas, with limited resources, seem unable to equip and prepare learners with the necessary literacy and numeracy skills that they should have obtained at a primary school level (Rural Education Draft Policy, 2017).

As seen above, there are many variables that can influence a learners' experience of learning in the classroom. An important variable to consider is the linguistic diversity in South African classrooms. The language in education policy is still influenced by the racialisation of language under apartheid as well as by new challenges such as internal African migration (Busch, 2010). South Africa has eleven recognized official languages (with South African Sign-Language being recognised as an official language in education), however, the South African language of learning and teaching is recognized to be predominantly English and Afrikaans (Busch, 2010). Although there is a constitutional recognition of language rights, it has not yet been translated into the language-in-education policy (Pluddemann, et al., 2004, as cited in, Busch, 2010). Many of the African language speaking families have been forced to send their children to English and Afrikaans schools, English being a growing interest as the medium of instruction in schools (Busch, 2010). This occurs at the expense of the learners' home languages with the expense that their home language has not been marginalised even in areas where English is not or rarely used (Busch, 2010). According to the Rural Education Policy (2017), indigenous knowledge systems and foreign languages can be seen as an asset in the education system, as it can enhance teaching and learning in the rural school systems. However, as mentioned above, this has not been considered. This exploitation of the learners' first language in learning and teaching is one of the understanding factors for poor academic achievement and high dropout rates (Alexander, 2000, as cited in, Busch, 2010).

In reference to Figure 2.1 above, there seem to be benefits to having English as a first language in relation to reading (Spaull, 2012). The tests conducted in schools are in English or Afrikaans (Spaull, 2012), therefore, having these languages as a first language would have significant benefits to the ease of learning and success of understanding the work provided.

At all grade levels, the learners are learning new vocabulary, new concepts, and learning complex terms that require a depth of language for understanding (Owen-Smith, 2010).

The language of learning and teaching versus the learners' home language has a strong role with the adequacy of acoustics in a classroom. The process of discriminating speech and proper pronunciation for intelligibility needs appropriate acoustic conditions (Petrasova, et al. 2016). Inadequate reverberation times have an influence on the intelligibility of pronunciation that could cause confusion during the educational process, especially if the lesson is not being taught in the learner's home language (Petrasova, Chmelik, & Rychtarikova, 2016). A study conducted by Peng (2014), explored how native and non-native English-speaking listeners performed on speech comprehension tasks under inadequate acoustic conditions. The conditions included English speech produced by a native English speaker versus a non-native English speaker who had an accent (Peng, 2014). The reverberation time was varied between 0.4 seconds to 1.2 seconds during the task (Peng, 2014). The results showed that the reverberation time affected the speech comprehension of the listeners, more so for the non-native English listeners than the native English listeners (Peng, 2014). The study concluded that reverberation time needs to be optimal in order for speech comprehension performance to improve for the non-native English-speaking population (Peng, 2014). This study is closely related to what the non-native English-speaking learners, who make up a high percentage of the population in South Africa experience on a daily basis. With new topics, vocabulary, and concepts being taught in a foreign language combined with poor acoustics that influence the intelligibility of speech in general, these learners are struggling to comprehend the lesson being taught. Nelson, Kohnert, Sabur, and Shaw (2005) conducted a study that explored the effects of classroom noise on attention and speech perception of typically developing learners who are listening through their second language and compared those results to the English-speaking learners.

The results portrayed that learners that are learning in their second language have a distinct disadvantage, such as, decreased speech recognition and intelligibility when listening in a room with adequate acoustic conditions (Nelson, et al., 2005). When there are inadequate acoustic conditions these disadvantages may be exacerbated.

After the legislation was changed following apartheid, the African National Congress (ANC) declared that all children should have access to free basic education (Fiske & Helen, 2003). However, once the ANC took power, they soon came to realise that there would be insufficient funding to equalize public funding at a level that was near to the education level that white learners had during apartheid (Fiske & Helen, 2003). Due to the free basic education, school fees have been abolished in the public sector and this has contributed to increased opportunities on learner enrollment (Fiske & Helen, 2003). However, it may contribute to lower school quality (Fiske & Helen, 2003). Due to the limited resources which may be caused by limited funding for education, the learners may have very little in their school environment to participate and succeed appropriately (Fiske & Helen, 2003). Due to the lack of funding in public schools, there may be fewer opportunities for the school to invest in additional resources such as qualified teachers that could assist in the enhancement of learner performance.

Another significant issue that classrooms in South African schools have is the pupil-teacher ratio. Pupil-teacher ratios seem to be largely disproportionate in South Africa. During apartheid the black-governed schools had a range of pupil-teacher ratio's from 23 to 67 learners per teacher (Case & Yogo, 1999). Post-apartheid there did not seem to be an instant change to the conditions of the schools (Case & Yogo, 1999). Resources may be limited in today's Department of Education and therefore there is not enough financial support to hire more qualified teachers in order to reduce the pupil-teacher ratio (Fiske & Helen, 2003; Case & Yogo, 1999).

2.2. Considering Technology in Education

The Department of Basic Education and the Department of Telecommunications came together to discuss the need for Information Communication Technology (ICT) in schools for teaching and learning purposes, not only for administrative roles (Gina & Kubayi, 2016). Gina and Kuyabi (2016) state that 54% of connectivity is focussed on in urban areas and only 33% is focussed on in rural areas. A national long term goal includes learners having tablets, teachers having laptops, and having electronic boards in each classroom (Gina & Kubayi, 2016; Action Plan to 2019, 2015). This goal has limitations, such as the speed of connectivity, training, the lifespan of the technology, and funding shortfalls (Gina & Kubayi, 2016). Teacher and learner training needs to take place so that technology can be used optimally. An issue with connectivity is the speed of the connection, which in many areas is very slow and causes delays that disrupt learning time (Gina & Kubayi, 2016). The Gauteng Department of Education referred to poor functionality and the issues of infrastructure in schools, and the classrooms were in dire need of modernisation (Gina & Kubayi, 2016). The concern that schools do not have electricity was discussed, and solar panels were suggested to solve the issue (Gina & Kubayi, 2016). There was a budget of R400 million to be used on infrastructure and ensuring that classrooms were refurbished according to the required standards and around R200 million was dedicated to devices and equipment needed for connectivity by the Provincial Treasury (Gina & Kubayi, 2016).

2.3. Sanitation in South African Schools

A South African radio station, 947, recently ran a crowd-funding initiative on the 19th of November 2018, also known as World Toilet Day (<http://www.947.co.za/articles/2018/11/19/support-anele-s-world-toilet-day-2018-crowdfunding-initiative>). An article was written to share the statistics of the schools in South

Africa and the deadly sanitation crisis that stands today. This deadly sanitation crisis was emphasised when a five-year-old, Michael Komape, drowned in a pit toilet in a school in Limpopo in 2014 (Ramaphosa, 2018). Unfortunately, this is not a single case scenario, the same scenario caused Lumka Mkethwa to lose her life in March 2018 in a school in the Eastern Cape (Ramaphosa, 2018). A recent audit revealed that 3800 schools are using dangerous pit toilets and other inappropriate facilities, while 2000 schools do not have access to sanitation (“The State of Toilets and Sanitation Around Schools in South Africa”, 2018). Following this audit, the president of South Africa, Cyril Ramaphosa, declared the Sanitation Appropriate for Education (SAFE) initiative in August 2018. The SAFE initiative was declared due to young and innocent learners experiencing tragic deaths due to the service delivery delay (Ramaphosa, 2018). The SAFE initiative will assist in restoring the dignity of learners in rural and township areas by ensuring the installation of appropriate sanitation facilities (Ramaphosa, 2018). The Revised Five-Year Strategic Plan (2016) has mentioned that the South African school infrastructure and safety backlog needs to be addressed to eradicate the schools that do not have access to running water, appropriate sanitation, and electricity. Referring back to the ecological framework, excellent educational outcomes cannot be expected when learners and teachers are exposed to an environment that is not conducive to learning and teaching (Ramaphosa, 2018). In the public school system over 11 000 schools have obtained flush toilets that are connected to the municipality or a septic tank to ensure safe disposal (Ramaphosa, 2018). The government of South Africa has also provided alternative sanitation technologies, where water connections are not possible, to 9600 schools (Ramaphosa, 2018). Despite this great progress, there are still many schools that need desperate intervention. The goal is set that by 2030, all schools in South Africa should have access to safe and appropriate sanitation facilities (Ramaphosa, 2018).

As understood by the aforementioned articles, many South African schools lack sanitation, the infrastructure of the schools seem to be less than ideal, and it seems that there is no budget for maintenance or improvements of current structures. The learners seem to be coming to school hungry, with no access to clean water, or sanitation. Under these circumstances, it is difficult to prioritise acoustics in a classroom, improving learning instruction, or assisting learners to achieve greatness when the learners' school is not creating a conducive or safe environment for them to learn in. According to the Revised Five-Year Strategic Plan (2016), a national school nutrition programme was underway to ensure that targeted learners were provided with nutritious meals on school days. This is a conditional grant, therefore, one cannot know if this was a success or if it is still being implemented in schools in South Africa.

2.4. Hierarchy for School Intervention

To understand where priorities lie in the hierarchy of schools' needs, one can apply the principles of Maslow's hierarchy of needs. Maslow explored the structure of human needs that was later structured in the form of a pyramid (Pichere & Cadiat, 2015). There are five levels of needs, namely, physiological needs, security needs, recognition needs, self-esteem needs, and self-actualization (Pichere & Cadiat, 2015). According to Maslow (2012), the human needs are arranged in a hierarchy of pre-potency; the presence of one need rests on prior satisfaction or dissatisfaction of other drives (Maslow, 2016). When applying Maslow's hierarchy of needs to an example of a South African school, many of the schools would be ranked at the basic survival and physiological level as depicted in Figure 2.2. At a basic survival level, schools in South Africa may not have sufficient resources or facilities to ensure focus on learning and teaching quality (Darling-Hammond, 2010). Maslow's hierarchy of needs is based on the individual needs of a single person. When applying these needs to a school it focuses on the school's environment and the learners' experiences which

allow them to meet their learning needs successfully. This hierarchy in a schools perspective looks at how a school’s structure can influence a learner’s ability to succeed and thrive. When applying Maslow’s hierarchy of needs to a school it could be represented in the pyramid below in Figure 2.2

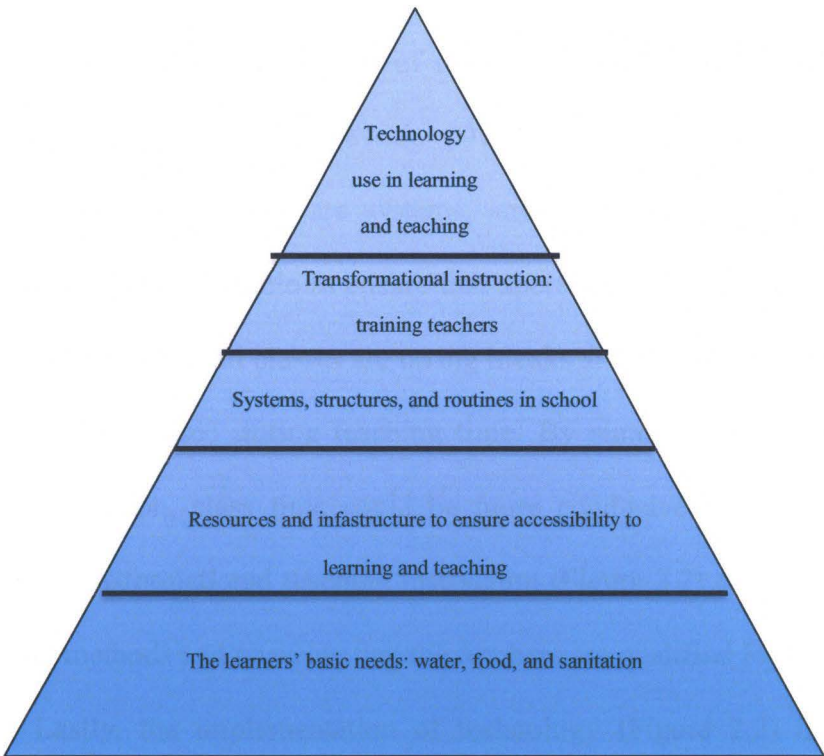


Figure 2.2. A school’s hierarchy of needs adapted from Maslow’s hierarchy of needs based on Spevack (2015).

Although this study focussed on classroom acoustics and the important influence it has on access to learning for all learners of all learning capabilities, one has to be realistic in the implementation of such acoustic treatments when many schools in the South African context are still on the basic needs level of the hierarchy (Figure 2.2). As mentioned before, 11000 schools have appropriate sanitation, yet 3800 are still in a dreadful sanitation crisis which needs to be prioritised to ensure safety to the learners (Ramaphosa, 2018). Therefore,

for those schools who are still awaiting sanitation intervention, this needs to be prioritised before implementing any sort of acoustic treatment into the classrooms. Although, for those schools who have the basic needs such as access to water, appropriate sanitation, and accessibility to food, one can begin to see the importance of implementing acoustic treatments into the classroom as part of improving the learning environment for the learners. Referring to Figure 2.2, following the infrastructure changes is the structure, systems, and routines level. Systems refer to a set of roles, responsibilities, and relationships that exist around accomplishing a goal (Spevack, 2015). Analysing how the school operates and performs is easier when there are systems, structures, and routines in place. This could include managing the timetable to ensure that sports are not being played while classes are running, or ensuring that all classes are taking breaks at the same time so that the recreational areas are not being used during teaching time. By simplifying the basic operational and instructional function, class time could be more conducive to learning from an external perspective. Transformational teaching instruction (Figure 2.2) refers to training teachers on new teaching methods and ensuring that the teachers are qualified for the service that they are providing. Lastly, the implementation of technology (Figure 2.2) into the classroom to advance learning and teaching styles while modernising the classrooms.

Hierarchy in education in South Africa was presented in an article by Mbiza (2018). The article provides statistics such as 90% of learners in Limpopo obtain a free lunch on a daily basis, whereas, only 17% of learners in schools in Limpopo have a library (Mbiza, 2018). Mbiza (2018) suggests that the lack of libraries is not necessarily due to a lack of funds but rather poor management of funds. This article discusses the prioritisation of needs and the necessity of certain resources, for example, food versus a library. In Gauteng, the statistics differ, 73% of learners obtain a free lunch, whereas, 83% of learners are in schools which provide resources, such as a library. Considering the above, it becomes important to

interrogate the prioritisation of needs, for example, refurbishment may be considered secondary in the bigger scheme of things.

According to the Action Plan to 2019 (2016) technological access in the classrooms as well as improvement in infrastructure are national goals that have been put in place to achieve improvements in learning and enrolments. In this document, Goal 20, which refers to technological access, precedes Goal 24, which refers to the improvement in physical infrastructure and environment of the school (Action Plan to 2019, 2015). These goals are ordered in levels of priority. This is of concern, as a number of schools in South Africa may be on the basic needs level, yet, technological access is being prioritised. It is important to understand that one can introduce resources, technology, and changes in teaching methods, but if the environment is not supportive to learners, especially those who may have learning difficulties or those that are second language English speakers (as mentioned previously), these advances may have very limited benefit due to the poor acoustic conditions in the classroom. As Goal 24 in the Action Plan to 2019 (2015, p. 2) states, “Ensure that the physical infrastructure and environment of every school inspire learners to want to come to school and learn, and teachers to teach.” This statement indicates the importance of having a hierarchy when providing intervention in an educational facility.

The Revised Five-Year Strategic Plan (2016) seems to have a hierarchy similar to Figure 2.2. The importance of establishing certain goals goes according to the following order (Revised Five-Year Strategic Plan, 2016, p. 58): “address the schools needing to be brought to basic safety functionality levels; replace all inappropriate schools structures; replace all mud schools that are mainly situated in the Eastern Cape, and upgrade schools to optimum functionality.” This hierarchy of needs seems to make sense when contextually applying it to existing schools in South Africa. As part of the ecological framework, all these

factors need to be taken into consideration when looking at the individual learner's internal and external environments that may play a major role in academic success.

2.5. Acoustics and Communication in the Classroom

Crandell and Smaldino (2000) suggest that the academic achievement of children whose hearing is within normal limits and typically developing may depend on the intelligibility of the acoustic transmission of information in the classroom. Perceiving speech in the classroom can often be influenced by the acoustic properties within the learning environment (Crandell & Smaldino, 2000). This can be further understood by understanding the link between the brain and the ear, which initiates when a learner enters the classroom (Savage, 2007). There are both the peripheral and central auditory systems collecting speech data and coding them for frequency, intensity, and timing qualities (Savage, 2007). These speech data are analysed and stored by the auditory processing centres of the brain (Savage, 2007). For listeners who have hearing within normal limits, slight variances in frequency, intensity, and timing are interpreted to determine the position and distance of the speaker, the size of the room, and simplicity of intelligibility (Savage, 2007). The brain interprets this information to assist the listeners in understanding their environment (Savage, 2007). When learners are exposed to classrooms with poor classroom acoustics, the noise and reverberation cause the central auditory system in the brain to identify reflection intervals within a few milliseconds (Savage, 2007). Thus, if the learning environment is not acoustically conducive, learners may experience difficulties in auditory processing of the information provided in class, which in turn could influence their overall academic achievements.

Noise levels and reverberation times have a major effect on the intelligibility of speech in the classroom (Dockrell & Shield, 2004). When learners are in a room that has

moderate acoustic damping, a conversation can take place with ease even though the surfaces of the room may be reflecting every syllable with various time delays (Savage, 2007).

Reverberation time is the time measured in seconds that it takes for the sound pressure level to deteriorate once the sound source has terminated (Klatte, Lachmann, & Meis, 2010). The American Speech-Language-Hearing Association (ASHA) defines reverberation as the sound that continues to exist even after the original sound has terminated, due to the sound waves reflecting off of surfaces (ASHA, 2015). Sound can reflect off of any surface within a room such as the floor, ceiling, furniture, and walls (Dockrell & Shield, 2004). Sound is more reflective on hard surfaces, thus creating a greater amount of sound reflection within the room (Dockrell & Shield, 2004). Reverberation could cause major obstructions with speech intelligibility, thus causing a barrier to learning (ASHA, 2015; Crandell & Smaldino, 2000).

Noise is measured in decibels (dB), a logarithmic unit, meaning that when sound energy is doubled the noise level is increased by 3dB (Pope, 2010, as cited in Kassuto, 2016). When one measures environmental noise, one uses the A-weighted decibel, dB (A), which is an estimation of how the human ear responds to sound (Pope, 2010). When noise levels are high in classrooms the poor acoustics can interfere with the teacher's ability to teach and the learner's ability to learn. The reverberant speech reaches the listener following the original signal and causes an overlap with the original signal triggering masking of speech (Crandell & Smaldino, 2000). Crandell and Smaldino (2000) show that acoustic conditions within a classroom can negatively influence speech perception due to high levels of ambient noise levels, long reverberation times, and poor signal-to-noise ratio of the teacher's voice to the background noise. This is further influenced by the distance between the learner and the teacher (Crandell & Smaldino, 2000). The Speech Transmission Index (STI) is a physical metric that is correlated with speech intelligibility and how it is degraded by ambient noise and reverberation (Goldsworthy & Greenberg, 2004). With reduced reverberation and

ambient noise levels, the STI tends to improve, meaning speech intelligibility within the given environment has improved. Masking of speech and a degraded STI can cause impaired academic performance due to poor acoustic conditions. This influence can be exacerbated when learners are exposed to complex listening tasks such as identification, mental processing of spoken information, and short-term storage, as mentioned in the rationale for the study (Klatte, et al., 2010). Impaired academic performance is common as learners have to have increased listening efforts which entails more cognitive resources to enable storage and processing of the spoken information (Klatte, et al., 2010).

As mentioned previously, a number of studies have shown that increased noise levels and poor classroom acoustics have significant effects on the following: concentration, behaviour in the classroom, attention, spelling and reading ability, and overall academic achievement (Gumenyuk, et al., 2004; Klatte, et al., 2010). It is noted that these abilities or skills are affected with typical learners within a typical classroom, which signifies concern regarding learners who may have remedial educational needs, learners who may have all these mentioned difficulties with or without noise in the classroom (Kassuto, 2016; Klatte, et al., 2010; Nelson, et al., 2005; Van Reenen & Karusseit, 2017). Klatte, et al. (2010) reported that learners who have special educational needs are more susceptible to impaired academic performance in inadequate listening conditions in comparison to typically developing children. Poor acoustics, heightened noise levels, and degraded STIs may affect the learners' learning experience in the classroom. However, it becomes a particular problem with learners who possess the following difficulties: auditory processing disorders, learning disabilities, learners with a hearing loss, speakers of another language (Nelson, Kohnert, Sabur, & Shaw, 2005), attention disorders, and language and speech delay (ASHA, 2015; Geffner, Lucker, & Koch, 1996). A South African study conducted by Seabi, Cockcroft, Goldschagg, and Greyling (2012), found that learners who are exposed to environmental noise, such as chronic

aircraft noise, and those who are speaking English as a second or third language have a higher chance of experiencing lower reading comprehension skills than those who are not in the same position. The ability to read and understand text is involved in nearly all areas of learning and is therefore imperative for the progression of academic success (Seabi et al., 2012). In poor acoustic conditions reading and understanding text difficulties are common, this is further illustrated by the following study. Another study conducted in South Africa by Hollander and de Andrade (2014), found that airport noise may have an impact on a learner's auditory language processing abilities. This means that a learner's ability to process auditory information provided by the teacher will be influenced by the level of noise in the learning environment. It is not only the learners who may have difficulty in an acoustically inadequate classroom but the teachers too (ASHA, 2015). Teachers use their voices for roughly sixty percent of the day, with inadequate classroom acoustics they are forced to increase their voice intensity levels in order to overcome the increased noise levels, in result straining their voices (ASHA, 2015). Thus, inadequate classroom acoustics may affect both the learners' and the teacher's experience in the classroom.

A common source of noise in the classroom is background noise. According to the American Speech-Language-Hearing Association (2015), background noise is any unwanted sound that interferes with the information or sounds that one is intending to hear. A study conducted by Kassuto (2016) in Johannesburg, South Africa, found that common sources of noise experienced in the classroom are: children generating noise, fans, intercom, electricity box, high school learners, lawn mower and leaf blower, and the sports field. The teachers found that the learners presented with the following in the presence of noise in the classroom: listening difficulties, distractibility, negative change in behaviour, and difficulty in task completion (Kassuto, 2016). Teachers are reported to have a lack of access to information regarding classroom acoustics and the effects of noise levels within the classroom (Goldberg

& Richburg, 2005). Teachers have attempted to improve their internal setting in the classroom in order to improve the poor acoustic environment. They attempt to deal with the presence of noise in the classroom by doing the following: changing seating arrangements, removing the internal source of noise (for example, turning off the fan), using discipline, and improving acoustics (Kassuto, 2016). The teachers feel helpless when it comes to improving the acoustics and need assistance from professionals who play a role in the acoustic treatment of classrooms (Kassuto, 2016). Despite the different types of noise that are influencing the teaching and learning experience in the classroom, access to information to improve the acoustical situation within a classroom seems to be limited.

2.6. Effects of Ambient Noise Levels in the Classroom

In the South African Schools Act 84 of 1996 notice of 2009, it is stated as part of the Architectural Norms and Standards section that acoustics need to be considered when developing and planning a school (Kassuto, 2016). It is specifically stated in Section 3.27. “Acoustics refers to noise levels within a set space” (Department of Education, 2009, p. 26; Kassuto, 2016). The following describes the norms for the noise levels: any open spaces cannot be smaller than 300 square metres; the quality and extent of the surfaces that are absorbent of sound need to be designed with the main goal of providing a general background noise of 40dBA to 50dBA (decibels) when this specific space is fully occupied; reverberation needs to be dealt with in relation to the volume of the space and quality of the surfaces, low reverberation time should be achieved between 0.6 seconds to 0.7 seconds; and classrooms should not be adjacent to a sports field (Department of Education, 2009; Kassuto, 2016).

In the South African Schools Act 84 of 1996 that was amended in 2013, it briefly states as part of the Design Considerations for all Education Areas the acoustic conditions that are needed within the classroom setting. According to the ninth consideration, acoustic

conditions should “facilitate clear communication of speech between teacher and learner, and between learners themselves, and should not impede teaching and learning activities.” (The South African Schools Act, 2013, p. 12; Kassuto, 2016). According to the tenth acoustic condition, reverberation and background noise should, “be reduced to a minimum” (The South African Schools Act, 2013, p. 12; Kassuto, 2016). The regulation for noise levels in the legislation within a classroom is very general and basic. There is no reference to who needs to be consulted with to ensure the appropriate acoustic measures and conditions are met within the classroom setting. The United Kingdom BB93 (Department for Education, 2015), the United States of America ANSI/ASA S12.60-2010 (Acoustical Society of America, 2010), the WHO guideline for community noise (Berglund, Lindvall, & Schwella, 1999), and the Association of Australian Acoustical Consultants Guideline for Education Facilities Acoustics (Association of Australian Acoustical Consultants, 2010) are all in agreement with the guidelines for ambient noise levels in the classroom, at 35dBA. When looking at the international acoustic guidelines and South African guidelines, it seems as though the South African guidelines are outdated.

A number of studies have indicated that classrooms are not meeting appropriate noise levels internationally and in South Africa. Van Tonder, Wolte, Strydom, Mahomed, and Swanepoel (2016) conducted research in South Africa and found that adequate lighting, room temperature, and seating arrangements are imperative in a classroom, including the noise levels which need to be appropriate for learning to be considered. Distraction is heightened with inadequate acoustics in the classroom. Learners with learning difficulties across the spectrum may have exacerbated learning difficulties when placed in a poor acoustic environment (van Tonder, et al., 2016; Kassuto, 2016). The study showed the average noise level was a 69dBA average in the baseline recording period, prior to intervention (van Tonder, et al., 2016). Further research was conducted by Losso, Viveriros, and Figueiredo

(2004) in Brazil: it was found that the ambient noise levels ranged from 51dBA to 70dBA in the classrooms tested. A Hawaiian study found mean occupied background noise levels to be at 46.6dBA in private schools and 52.1dBA in public schools (Pugh, Miura, & Asahara, 2006). Two American studies conducted in acoustically untreated classrooms were found to have ambient noise levels of 56dBA (Hodgson, 1994; MacKenzie, 2000). Research was reviewed by Picard and Bradley (2001) whereby the noise levels in American occupied classrooms ranged from 42dBA to 94dBA. Shield and Dockrell (2003) measured occupied classrooms in America showing ambient noise levels ranging from 56dBA to 77dBA. The previously mentioned study showed that especially during interaction times, such as group work, the noise levels were at a mean level of 65dBA with an overall mean of 72dBA. Another study conducted in an occupied classroom was conducted by Hay (1995): a survey was used to measure seven occupied classrooms in America where learners were actively working and talking. The noise levels varied from 58dBA to 72dBA (Hay, 1995). In acoustically untreated and occupied classrooms even higher levels of 77.3dBA were measured in a study by MacKenzie (2000). Kassuto (2016) conducted a study whereby the noise levels ranged between 60.8dBA to 70.8 dBA in occupied classrooms in a South African school. The above mentioned research studies show that classrooms all over the world are not meeting acoustic standards, thus, teachers and learners are working in environments that are not conducive or supportive towards accessible education.

The aforementioned research shows noise levels are well above the South African recommendation for classroom noise levels, which is between 40dBA to 50dBA. The acoustic standards and norms in South Africa are very vague and difficult to follow. Ramma (2007) conducted a study in South Africa where it was found that South African classrooms may not be meeting acoustic standards in regard to reverberation and ambient noise levels. A research study focussed on South African architects' considerations in classroom acoustics

revealed that architects would want the following to be included in an ideal policy: financially considered regulations such as, cost-effective materials, regulations that can be easily implemented, materials for use in buildings that are economically viable, and sound transmission guidelines (Ryder, 2017). South African based research in classroom noise levels is very limited across all types of classrooms.

South African schools are commonly prefabricated buildings that consist of thin walls (Hollander & de Andrade, 2013). Schools that are made up of brick have poor acoustics due to the inadequate windows and doors, and there is not enough absorbing material for sounds (Hollander & de Andrade, 2013). This causes an unacceptable signal-to-noise ratio within the learning environment (Hollander & de Andrade, 2013). The refurbishment or acoustic treatments that are needed within the classrooms can be very costly (Higgins, Hall, Wall, Woolner, & McCaughey, 2005), and within a South African context, this needs to be considered. Therefore the solution for acoustic treatments needs to include the least cost with the most value.

There is considerable research suggesting low-cost options to lower reverberation times and ambient noise levels in order to improve the overall acoustics of the classroom (e.g. Siebein, Gold, Siebein, & Ermann, 2000; Hollander & de Andrade, 2013). However, there is little to no research indicating the effect of the acoustic treatment on reverberation times and ambient noise levels in the classroom, nor the efficiency and practicality of their installation (Stonestreet, 2016; Ramma, 2007). In South Africa, the research is little to none, especially on those focussing on solutions in the well-known and growing issue of inadequate classroom acoustics.

2.7. Reverberation and Sound Absorption

There are national and international norms for reverberation time (seconds). The American Speech-Language-Hearing Association (ASHA) recommend that reverberation time should not exceed 0.4 seconds (ASHA Working Group on Classroom Acoustics, 2005). Crandell & Smaldino (2000) recommend that reverberation times should be around 0.4 seconds for learners with learning difficulties, and Peng (2014) recommended that reverberation time should be around 0.6 seconds for learners who are being taught in a second language. The United Kingdom BB93 (Department for Education, 2015), the United States of America ANSI/ASA S12.60-2010 (Acoustical Society of America, 2010), the WHO guideline for community noise (Berglund, Lindvall, & Schwella, 1999) and the Association of Australian Acoustical Consultants Guideline for Education Facilities Acoustics (Association of Australian Acoustical Consultants, 2010) are all in agreement with the guidelines for a reverberation time of below 0.6 seconds. In South Africa, the Department of Education released guidelines in 2012 for reverberation times of 0.6 seconds to 0.7 seconds. The SANS 10130 (2008) recommends that ambient noise levels should not exceed 35dBA in an unoccupied space, however there is no guideline referring to reverberation times. The Acoustical Society of America (2010) suggests that the reverberation time should not exceed 0.6 seconds within a smaller built classroom and 0.7 seconds in a larger built classroom. International reverberation time norms seem to be more official than South African norms which could influence the acoustic quality of the existing classrooms in South Africa.

South African research has suggested that national classrooms may not be achieving appropriate reverberation times due to inadequate structures in the classroom. Ramma (2007) conducted a study in South Africa where it was found that South African classrooms may not be meeting acoustic standards in regard to reverberation and ambient noise levels. The study included the measurement of reverberation and ambient noise levels in 15 occupied and

unoccupied classroom within the Johannesburg area in the Gauteng province. It was found that 13 of 15 unoccupied classrooms were above the ANSI and WHO recommendations of 0.6 seconds (Ramma, 2007). Another study conducted by Kassuto (2016) in a private, mainstream, primary school within the Johannesburg area showed that occupied classrooms during real-time lessons presented with measured noise levels which were significantly higher than the recommendation suggested in the South African Schools Act 84 of 1996 notice of 2009. In addition to measuring the noise levels in the classroom, an observational survey was conducted and found that all classrooms showed inadequacy in structure, absorptive materials, and layouts of the classroom (Kassuto, 2016), all of which are influential contributors to the reverberation time and ambient noise levels in the classroom. The teachers of each of the measured classrooms were interviewed to gain insight of their experiences, knowledge, and perceptions of the effects of the noise levels on the learners in their classrooms, which were overall very negative. None of the teachers knew how to effectively acoustically treat their classrooms, or how to control the noise whether it was external or internal.

When treating reverberation in a classroom, one has to look at certain materials that have the ability to either reflect or absorb sound. Sound absorptive materials are effective in reducing the reverberation time as well as noise levels within a room. Sound absorption can be measured with the absorption coefficient (α) (Cowen, 2007; Stonestreet, 2016). This refers to the ratio of the occurrence of sound energy to the absorbed sound energy. When a given material does not successfully absorb any sort of sound in its surrounding, the absorption coefficient is zero (0) (Cowen, 2007). However, if a material absorbs all the sound in its surrounding, the absorption coefficient is one (1) (Cowen, 2007). Since materials absorb some sound, not necessarily all or none, the absorption coefficient measures of zero and one are the upper and lower limits (Cowen, 2007; Everest & Pohlmann, 2009; Stonestreet, 2016).

The frequency spectrum used in a classroom is between 125Hz to 8000Hz, typically these frequencies are used for processing speech (Bradley, 2002). The absorption coefficient will typically increase (towards the value one) as frequency increases (towards 8000Hz) (Cowen, 2007). Therefore it appears as though frequencies below 250Hz will have limited effectiveness, as they will be closer to the absorption coefficient of zero (Cowen, 2007; Stonestreet, 2016). Cowen (2007) explains that there is an arithmetic average of a material's absorption or reflective coefficient at 250Hz, 500Hz, 1000Hz, and 2000Hz called the noise reduction coefficient (NRC). Materials that have a NRC value of less than 0.20 are considered to be reflective, while materials that have a NRC value greater than 0.40 are considered to be absorptive (Cowen, 2007). The more absorptive the material, the higher the absorption coefficient.

Research conveys suggestions for low-cost methods in improving classroom acoustics, however, the literature is limited to the methods of doing so, especially in relation to the classroom environment.

2.8. Ambient Noise Levels Versus Reverberation Time: The Importance of Prioritising Each in Acoustic Treatments.

When looking at acoustically treating an existing classroom, one questions whether emphasis should be on treating the reverberation time or treating the ambient noise level. In the ideal world, treating both would be the most beneficial to creating the 'perfect' learning environment. However, budget constraints and limitation of resources do not always allow for this dual treatment of acoustics.

To determine which treatment, reverberation time versus ambient noise level, is more viable, one has to delve into the research available to determine the prioritisation of treatment. The effect of reverberation on speech intelligibility by learners with hearing loss

was found to be much greater than the effect of background noise (Hazrati & Loizou, 2012). It is understood that the co-existence of both poor reverberation and noise levels can cause detrimental effects on a learner's ability to learn in the classroom. Reverberation in a classroom causes overlap masking and reduces the low-frequency information from a signal which is imperative for speech intelligibility (Hazrati & Loizou, 2012), whereas background noise masks weak syllables but is not dependent on the energy of the preceding segments (Nabelek, et al., 1989). A study conducted by Whitmal and Poissant (2009) found that speech intelligibility was worse when the reverberation time was inadequate than when the ambient noise level was inadequate. Another study conducted by Kokkinakis, et al. (2011) looked at learners who had cochlear implants, the study showed that with an increase in reverberation time there was a decrease in word recognition ability, to be more specific, the learners had a mean recognition score of 90% which dropped to 20% when reverberation time increased. Studies conducted by Poissant, et al. (2006), and Kokkinakis and Loizou (2011) showed that intelligibility of speech drops by 60% when the reverberation time is increased, and a study by Nelson, et al. (2003) shows that with an increase of background noise speech intelligibility drops by 50%. This shows that reverberation time has more of a negative effect on speech intelligibility than ambient noise levels in a learning environment. Noise can often only be treated by treating the source of noise, however, this is not always possible. Gelfand and Silman (1979) suggest that performance in noise is related to the reverberant energy that predicts performance in reverberation, meaning that the effects of noise are worsened in reverberant spaces. Treating both the reverberation time and the ambient noise level would be most beneficial in the improvement of acoustics. However, when there are financial limitations, one needs to prioritise acoustic treatments. The above research seems to suggest that reverberation time has a more significant effect on learning in the classroom than

increased noise levels. This suggests that in a classroom setting, reverberation time should be treated prior to increased noise levels.

2.9. Methods of Acoustically Treating Classrooms

Acoustically treating an existing classroom to improve the acoustics relates to the reverberation time (RT). As mentioned previously, reverberation is sound that continues to be present within a room even after the original sound has ceased, due to the sound waves reflecting off of surfaces (ASHA, 2015).

Appropriate acoustic conditions within a classroom are closely related to the learning processes of the learners (Paulo & Coelho, 2009). Reverberation times depend on the size of the space and the amount of sound absorption present. An atmosphere within a classroom should encourage interest in listening and interaction in communication (Paulo & Coelho, 2009). Acoustic conditions can influence the efficiency of a learning environment (Paulo & Coelho, 2009).

Solutions have been suggested in various research studies. One solution for a reverberant space is to add acoustic absorbers (Cox & D'Antonio, 2009) as this reduces the sound energy from reflecting in the room. The best place for absorption seems to be on the ceiling or high up on the walls (Cox & D'Antonio, 2009; Chermak & Musiek, 2014). Acoustically treating a classroom can include covering the ceiling area with sound absorption materials that need to be distributed in certain parts of the ceiling area (Paulo & Coelho, 2009; Chermak & Musiek, 2014). This form of acoustical treatment enhances the reflection of early sound energy more efficiently to the learners in the classroom (Paulo & Coelho, 2009). The treated areas need to be covered with the same type of material but with different thickness to control the reverberation (Paulo & Coelho, 2009). This treatment is advantageous as it does not visually impose on the space as being an additional treatment but

rather being architectural and absorptive (Cox & D'Antonio, 2009). A less expensive solution is to install absorbent ceiling tiles made out of compressed mineral wool mounted in a T-bar grid (Cox & D'Antonio, 2009). Micro-perforated absorbers can be applied with wood veneers which allow architects to use absorbing wood panelling with traditional reflective wood panelling (Cox & D'Antonio, 2009). Achieving the adequate amount of reverberation in a space is important to the design, to ensure that the function of the room is ideally met, for example, in a classroom making speech intelligible and reducing noise levels to create an ideal learning environment (Cox & D'Antonio, 2009).

According to the British Society of Audiology (2011), modifying the listening environment can assist in the management of learners who have an auditory processing disorder. The BSA (2011) and American Speech-Language-Hearing Association (2018) recommend making acoustic changes to the environment in order to reduce noise and reverberation. As part of these recommendations acoustic treatments such as implementing carpets, curtains, putting seals on doors, turning off noisy equipment when not in use, replacing noisy light fixtures, placing tables at an angle to improve reverberation, double glazed windows, vertical blinds on the windows, rubber shoes on the furniture, covering hard surfaces with absorptive surfaces like acoustic panelling, and cork boards to reduce reverberation times (ASHA, 2018; Bamio et al, 2006, as cited in BSA, 2011). The use of acoustic panels can enhance speech intelligibility due to the increased sound absorption and improved flutter echo (Ecophon, 2018).

Many of the above mentioned research mentions the use of carpeting or changing the floor to improve the acoustics within the classroom. DiSarno, Schowalter, and Grassa (2002) indicate that the use of carpets on the floor can help reduce the reverberation time as the floor makes up 30% of the classroom's surface. However, the carpet has very limited effect on absorption of sound (DiSarno, Schowalter, & Grassa, 2002). A number of studies have

indicated that the use of carpeting or vinyl flooring is actually used to reduce the noise generation from flooring material that is noisy from furniture movement and people walking (Cavanaugh, Tocci, & Wilkes, 2010; Hegarty et al., 1998; National Deaf Children's Society, 2016; Peters, Smith, & Hollins, 2011).

Stonestreet (2016) conducted research in South Africa exploring the effects of low-cost sound absorbing furnishings on reverberation time and ambient noise levels. Stonestreet (2016) found that the combination of materials and furnishing reduced the reverberation time in the unoccupied classroom significantly from the lower to higher frequencies, especially between the frequencies of 500Hz to 2000Hz which are vital for speech intelligibility (Bradley, 2002). The research concluded that curtains and carpeting are effective and are low-cost sound absorbing materials which can reduce reverberation times in an unoccupied classroom (Bridger, 2003; Cowan, 2007; McCauley, 2001; Phillips & Griebel, 2003; Ramma, 2007; Shane, Kandil, & Schexnayder, 2012; Stonestreet, 2016; Thomas, 1999; Thomas, 1999). Curtains hung with appropriate airspace between the window and fabric are effective in reducing reverberation between the 250Hz to 1000Hz range (Cowan, 2007; Everest & Pohlmann; Stonestreet, 2016). Carpeting proved to be effective in reducing reverberation in the 2000Hz to 8000Hz range (Stonestreet, 2016). Unfortunately, the results cannot be generalised to all classrooms as there is a high dependency on the starting reverberation time and whether curtains and carpets will be enough to reduce the reverberation time to an appropriate level. The research was also conducted in unoccupied classrooms, whereas acoustics are truly important as learning takes place when classrooms are occupied which is a more realistic representation of the classroom environment. The tests were conducted in an unoccupied room as standards for reverberation times and ambient noise levels in classrooms are usually standardised in unoccupied classrooms (Knecht, Nelson, Whitelaw, & Feth, 2002; Nelson, Smaldino, Erler, & Garstecki, 2008).

Siebien, et al. (2000) suggested that the use of sound-absorbing surfaces, such as gypsum board on the walls and ceilings could assist in reducing reverberation and noise levels within a room. Hollander and de Andrade (2013) reported that the use of soft surfaces may help absorb sound, for example, placing carpets on a hard surface floor, using blinds or curtains to cover windows, and using felt bulletin boards or carpet squares to cover parts of the walls.

Research has shown that by using mechanical ventilation (a cooling or heating system, e.g. airconditioner) the doors and windows can be closed, and sealed with weather strips, which reduces the amount of noise entering the classroom (Ashcroft, 1992; Crocker, 1998; Crocker & Kessler, 2018; Hopkins, 2007). Once the windows and door are sealed the need for a mechanical ventilation system is heightened (Asselineau, 2015). Many research studies show that the need for good air quality and lowered temperatures are imperative in the learning process (Van Tonder et al., 2016; Wargocki & Wyon, 2006b; Yang, Becerik-Gerber, & Mino, 2013). Bako-Biro et al. (2011) reported that appropriate ventilation can affect learners abilities to concentrate, their memory capability, and their attention.

There are other methods of acoustically treating a space, such as, seating arrangements, egg crates, and using furniture. As mentioned previously with the study conducted by Kassuto (2016), the participants mentioned using adjusting seating arrangements to manage the internal source of the noise. This was supported by studies that showed a relationship between seating arrangements and the physical environment (Guardino & Antia, 2012; Siebein, Gold, Siebein, & Ermann, 2000; Wannarka & Ruhl, 2008). Egg crates are commonly known as a cheap alternative to acoustically treat a space. However, research indicates that the benefit of using egg crates is very limited due to the very low absorption qualities (Moss & Wiesenfeld, 1995). Egg crates do not assist with improving noise but can assist with absorbing excess reverberation (Crandell, Smaldino, & Flexer, 1995;

DiSarno, Schowalter, and Grassa, 2002). Furniture can be used to absorb sound and reverberation; furniture can also be used to diffuse sound and redirect it towards the absorptive ceiling (Chou & Hsia, 2013; DiSarno, Schowalter, & Grassa, 2002; Ecophon, 2018; Nilsson, Andersson, & Chigot, 2006).

As seen above, there are several methods to acoustically treat a space, however, low-cost applications are difficult to find. The inclusion of appropriate professionals is vital in the acoustic treatment of a space as their experience and collaboration can assist in achieving a common goal of improving the acoustics in a space.

2.10. Role of Architects

When new classrooms are required, architects may be one of the professionals that are in the projects team. According to South African Institute of Architects (SAIA) (2014), architects are trained and educated to provide critical judgment, specialist knowledge, leadership, capacity, and skills for the development and designs of the built environment. Their role, however, does not only cover the built environment but the experience of the environment too. According to *Vitruvius Principles of Good Architecture*, there are three principles of good architecture, including *firmitatis* (durability), *utilitas* (utility), and *venustatis* (beauty) (Brophy & Lewis, 2011). Within an educational facility, *utilitas* (utility) may refer to the space that should be functional for the people who are using it. This refers to the learners in the classroom having an educational space that encourages ease of access to learning which involves the light, temperature, movement, and acoustics of the room.

As mentioned previously, there are significant negative effects of poor classroom acoustics on learners in the classroom. This goes for learners with typical or atypical learning abilities. Research conducted by Ryder (2017) in South Africa revealed that a large percentage of her participants who were architects did not always consider the effects of poor

classroom acoustics on learners' access to education. A number of the participants mentioned that they would consider acoustics for classrooms where learners with learning difficulties were taught but not for a classroom where learners who have typical learning abilities were taught. The participants were unaware of the severe effects that poor classroom acoustics could have on access to education, especially with learners of both typical and atypical learning abilities. When Ryder (2017) asked if the participants made use of any norms and standards regulating acoustics when designing educational facilities, 63.6% of the participants reported that they do not use the norms and standards and only 36.4% reported that they make full use of the norms and standards. This indicated that the classrooms designed by the 63.6% participants who do not use the South African norms and standards may be acoustically inadequate which in turn could be creating a major barrier to learning in the classroom for both typically and atypically developing learners. In the same study, 75% of the participants did not know that the South African norms and standards existed, and 86.4% of the participants stated that they had never conducted testing in their designed classrooms for reverberation times and noise levels. Although acoustic consultants are involved in the process of testing for reverberation and background noise levels, architects play a very important role (ASHA, 2005). The above study shows a possible gap in awareness of the importance of considering acoustics in the classroom, and architects may not be fulfilling their role in acoustics in educational facilities.

2.11. Role of Acoustic Consultants

There are two major roles of the acoustic consultant, either during the first design process for new construction of a building and secondly in the refurbishment of an existing building (ASHA, 2005). Their scope of practice in these spaces includes interior room acoustics, interior and exterior acoustical isolation, noise control with mechanical systems, and sound reinforcement system design performance (ASHA, 2005). The acoustic consultant

evaluates the design and determines corrective measures needed to improve the existing acoustic conditions of the space (ASHA, 2005).

Acoustic consultants are professionals who specialise in acoustics as they have knowledge, insights, and information that can be complementary to the architectural design in creating the ideal acoustically adequate classroom (NCAC, 2018). Acoustical engineering is a highly specialized field that works with the art and science of sound transmission, interference, absorption, reflection, and refraction (Kriefwe, 2018). They also ensure that buildings comply with the regulations and standards and to minimize external noise, for example, road or air traffic (NCAC, 2018).

Architectural acoustics involves all areas of acoustical design for all types of architectural spaces, which allows for the optimization of the given environment and the many functions it may embrace, such as learning, communication, and productivity (NCAC, 2018). An acoustic consultant has a role specifically in the field of construction and architecture (Kriefwe, 2018). An acoustic consultant will use sound absorbing materials such as mineral fibreboard and fiberglass, and carpets when sound absorption is needed (Kriefwe, 2018). Sound reflecting materials such as drywall, vinyl, wood, plaster, gypsum board, concrete, and stone will be used when the sounds need to be reflected back to the listeners (Kriefwe, 2018). Acoustic consultants have a degree in acoustic engineering that includes the tasks of analysing acoustic designs, performing acoustic tests, and integrating engineering resources for a project.

2.12. Role of Educational Audiologists

Audiologists, especially educational audiologists, are taught to understand the principles of sound acoustical design and how educational outcomes rely immensely on the adequacy of acoustics in the classroom (ASHA, 2015). Educational audiologists are

responsible for managing individualised services for a child who may have a hearing loss and/or is obtaining special educational services (Johnson & Seaton, 2012). These audiologists work with several individuals to ensure appropriate services and classroom accommodations are made, such as the general and special education teachers, the learners, parents, and other relevant individuals in the child's life (Johnson & Seaton, 2012). Educational audiologists also have a role in bringing awareness and educating others of the concerns surrounding classroom acoustics, and how it may affect listening and learning (ASHA, 2015). It is important for audiologists to emphasise the need for adequate acoustical design in the planning of classroom layouts (ASHA, 2015). Within the typical classroom, the main method of communication between the teacher and the learners is an auditory-verbal method, where listening is an essential modality to receive information for learning purposes (Palmer, 1997, Kassuto, 2016). Educational audiologists are also involved in the surveying of the classroom acoustic conditions, measuring noise levels (in decibels), reverberation time (seconds), and signal-to-noise ratio, and comparing these measurements to norms and standards that are recommended within the given country (ASHA, 2015). Once the data are obtained, the audiologist needs to recommend strategies or technology to improve the acoustics, or recommend the involvement of an acoustic consultant to make recommendations for the classroom. The involvement of appropriate professionals can assist in achieving adequate classroom acoustics by implementing their suggested physical alterations (ASHA, 2015). The audiologists need to ensure that the modifications introduced should be enhancing the listening environment (Allen, Blake-Rahter, Heavener, Phillips, Redmond, Rosenberg, & Stigers, 1999). Audiologists have been described as resources to whom speech-language pathologists, teachers, principals, and parents can refer in order to reduce learning and listening barriers within the classroom (ASHA, 2015; Goldberg & Richburg, 2005). This is done by ensuring that the classroom acoustics and noise levels are meeting the set regulations

and standards in the given context. The involvement of audiologists in educational facilities has proven to be beneficial as learners can benefit from intervention which involves the development of listening skills, establishing accessible acoustic environments, and instructions to prevent hearing loss (ASHA, 2002). Audiologists have the responsibility to ensure that all learners in the classroom are supported from communication, academic, and psychosocial development needs (ASHA, 2002). A study conducted by Rosenberg, et al. (1999) showed that the involvement of audiologists in the classroom can assist learners' listening and learning behaviours with ensuring that the acoustic environment is appropriate for learning. Providing acoustic support in the classroom provides learners with the ability to reach their academic potential (ASHA, 2002).

2.13. Chapter Summary

Literature demonstrates that poor classroom acoustics and high noise levels have significant and negative effects on the learners learning in the classroom. However, the literature is limited on effective and low-cost methods to improve the acoustics in existing classrooms, especially for professionals to follow and implement in making a positive change in learners' learning environments. This dissertation thus focussed on gaining information from architects and acoustic consultants, on their experiences, skills, practice, and knowledge in low-cost and effective methods in improving acoustics and noise levels in existing classrooms. By gaining these insights and data, it can begin the development of an acoustic protocol which professionals such as educational audiologists, architects, and acoustic consultants could use to ensure the adequacy of acoustics within classrooms, in the South African context. This will also raise awareness of the significance of the problem of poor classroom acoustics and could build a foundation to further research on the topic.

Chapter 3: Methodology

This research study had various aims and objectives to achieve, therefore the researcher designed a systematic methodology to obtain the necessary information to answer the main research question. Qualitative data collection preceded quantitative data collection both of which provided a depth of data. The researcher explained how the data was collected and analysed, revealing the multiple data sources, data collection methods, and analysis methods within the data sets and across the methodological paradigms.

3.1. Research Question

What do architects and acoustic consultants suggest as low-cost and effective measures to acoustically treat existing classrooms, within the South African context?

3.2. Aims and Objectives

3.2.1. Primary aim of the study.

1. To obtain architects' low-cost considerations to acoustically treat existing or example classrooms.
2. To obtain acoustic consultants' low-cost considerations to acoustically treat existing or example classrooms.

3.2.2. Secondary objectives of the study.

1. To determine the participants' reasoning for their considerations to acoustically treat existing classrooms via drawings and semi-structured interviews.
2. To determine the low-cost considerations to acoustically treat existing classrooms by utilising the Sabine equation for reverberation times.

3.3. Research Design

3.3.1. Research procedures.

3.3.1.1. Ethics.

Non-medical ethical clearance was obtained from the Human Research Ethics Committee. In order to obtain ethical clearance, one has to explain the research process and the involvement of the participants. Due to the research being conducted with individual participants, their permission to participate in the study was valid for consent and therefore ethical clearance was provided to the researcher with an ethics certificate (Appendix A), and with an ethics protocol number of H18/04/11.

3.3.1.1.1. Ethics: Permission, consent, and methodology.

Once non-medical ethical clearance was obtained, the research process began. The participants were given information sheets which outlined the vital information regarding the research and the steps in that it would continue to proceed. Each phase of the research had individual information sheets for the participants to read (Appendix C and D) that provided the participants with information about the study and their participation in the study. A separate consent form was sent with the information sheet for participants to complete if they agreed to participate (Appendix E). The names and contact details of the participants were only known by the researcher. Information sheets (Appendix C) were emailed to different participants and to architectural and acoustic consultant firms/companies (Appendix F) to obtain more participants. Individual emails were sent to ensure anonymity of the firms' involvement in the research.

3.3.2. Participants.

Based on the primary aims and the literature review this project sought to elicit information from architects and acoustic engineers, more details of which will be provided under sampling criteria.

3.3.2.1. Sample size.

A total of ten participants were recruited including five architects and five acoustic consultants. Architects were included as schools may use them with regard to their professional advice for building classrooms. Acoustic consultants were used in the research study due to their highly specialised knowledge in acoustics. By including acoustic consultants it allows for an expansion of information which may assist or be complementary to the architects' practical designs. Research in the area of classroom acoustics in South Africa has not yet included acoustic consultants (Ryder, 2017).

3.3.2.2. Sampling criteria.

3.3.2.2.1. Architects.

Inclusion criteria:

- Qualified architects, as per the requirement set out by SAIA.
- Architects who have a minimum of one-year practical experience.
- Architects who have or have had exposure and experience in the design and construction of an educational facility.

Exclusion criteria:

- Unqualified architects, for example, student architects
- Architects who do not have one-year practical experience.

- Architects who do not have experience of the design or construction of educational facilities.

3.3.2.2.2. Acoustic consultants or engineers.

Inclusion criteria:

- Qualified acoustic consultants or engineers as per the requirements
- Acoustic consultants or engineers who have at least one-year practical experience.
- Acoustic consultants or engineers who have or have had exposure and experience in the design and construction in an educational facility will be beneficial. However, due to their specialty, any experience in acoustical treatment was sufficient for this research study.

Exclusion criteria:

- Unqualified acoustic consultants or engineers.
- Acoustic consultants or engineers who do not have a minimum of one-year practical experience.

3.3.2.3. Sampling strategy.

In the earlier stages of the research, snowball sampling method was used to recruit participants for this study. Snowball sampling is a non-probability sampling method which is often used for the study of rare or sensitive events occurring in populations (Rajaretnam, 2016). There are two types of referrals made within this sampling strategy. Firstly, each identified member of the target population was asked to identify other individuals who belong to the same target population (Wegner, 2007). Secondly, the members from the target population assist in the identification of some members they know or come across

(Rajaretnam, 2016). Snowball sampling increases the efficiency of the study as the researcher is gathering information about a certain population (Rajaretnam, 2016). The method relies on the researcher's ability to network and find appropriate participants (Rajaretnam, 2016). Although non-probability sampling can introduce bias into the statistical findings (Wegner, 2007) the researcher used the inclusion criteria to obtain further members of the population via snowballing. This allows for the validity and reliability of the participants chosen and therefore prevents the introduction of bias. The researcher emailed a cover letter to architect and acoustic consultant firms/companies (Appendix E) with a general information letter (Appendix B) to begin the snowball sampling. The letter explained and included information regarding the research study, as well as inclusion criteria to help guide the individual pass on the information to appropriate and possible participants.

The suggestions from phase two were converted into numerical data and placed into the Sabine equation to determine reverberation time. More detail of this data conversion will be explained later. Purposive sampling was used for phase three by including the interviews and drawings from phase two as data for analysis. According to Fraenkel and Wallen (1993), this is a non-random sample that is selected due to previous knowledge that suggests it is a suitable representative or because those that are selected have the information that is needed for the study.

3.3.3. Data collection.

3.3.3.1. Pilot study.

Once ethical clearance was obtained from the Human Research Ethics Committee, the researcher began the process of collecting data. However, prior to the main data collection, the researcher conducted a pilot study in an attempt to optimize the validity of the qualitative phases of the research and to interrogate the process of the study that would be followed for

the main research project. A pilot study needed to be conducted before the main data collection phase (Riazi, 2016), in an attempt to identify any problem that may arise and affect the quality and validity of the results (Blessing & Chakrabarti, 2009). This allowed the researcher to make any necessary changes to methods or questions based on the results of the pilot study (Riazi, 2016). Changes to methods or changing the format of asking questions or adding other methods to capture details from the participants were looked at (Blessing & Chakrabarti, 2009). This enabled the researcher to evaluate the length of the interview and need for adjustments. Out of all the participants that agreed to participate in the study one was randomly selected, an architect, to take part of the pilot study in order to make suggestions about the data collection materials and improvements for the interview. This added to the efficiency and effectiveness of the study. The pilot study covered phases one and two only, and the participant was made aware of this via an information sheet and consent form (Appendix B).

From the pilot study, the researcher noticed that conducting the live drawing prior to the semi-structured interview was unnecessary. The semi-structured interview guide naturally took place during the drawing procedure as the participant would talk about and explain her designs to acoustically treat the classroom while the interviewer commenced the semi-structured interview guide. The pilot participant suggested that the interviewer bring more copies of the printed illustrations of the classrooms so that, should the other participants need to present more than one idea, they would be able to do so on the appropriate sections that represented the classroom. The main data collection process was conducted in the same process as the pilot study due to the success of simultaneously conducting the semi-structured interview guide with the live drawing. The researcher was confident with using a digital audio recording device as well as describing the purpose of the research in a way that the participant could understand the objective of the study.

Since there are very few acoustic engineers and architects involved in the development of schools in South Africa, the sample size was a limitation in the study. Due to the pilot study being conducted with the same methodology that all the semi-structured interviews and live drawings were conducted in, the researcher used the pilot study data in the main study. The sample participant signed the consent form indicating that the interview conducted may not be used in the main research study, indicating that the pilot interview may still be used (Appendix B). The sample participant in the pilot study was an exact representation of the population considered for the main study. There are researchers in health science who recommend and allow the inclusion of pilot studies within the main study; based on the condition that the same methodology was followed, in order to strengthen the findings of the main study (Thabane, et al., 2010).

3.3.3.2. Phases of data collection.

3.3.3.2.1. Phase one.

The participants were emailed images (Appendix G) of the example classroom and an information sheet (Appendix D) including all the information that the participant would need to give informed consent as well as be informed on the process of the data collection. Prior to the phase two semi-structured interview guide the participant was given information regarding an existing classroom scenario, presented in Table 3.1 and illustrated in Figure 3.1 below. The information provided in Table 3.1 was based on research conducted by Kassuto (2016) with the use of the adapted *Classroom Acoustical Screening Survey Worksheet* by Johnson and Smaldino (2010).

Table 3.1

Table showing information, measurements, and details of the example classroom.

<u>Information about the example classroom</u>	<u>Measurements and details of classroom</u>
Dimensions of the classroom (mm²) *	8220 x 7060
Average dB (A) of the ambient noise level in the occupied classroom *	70,8 dB (A)
Reverberation time (seconds)	1,4 seconds
Physical characteristics of the classroom (background noise contributors) * <i>Sound Insulation Factors</i>	- The fans are audible - External (background) noise is audible - Noise from the road is audible - Sounds from other classrooms are audible - The hallway is audible (other learners)
Physical characteristics of the classroom (reverberation contributors) * <i>Sound Absorption Factors</i>	- Hard surfaces surround the classroom - Ceiling height is 2800 mm T. O. C. (Top of Concrete) - The ceiling is assumed to be 170mm deep - There are no acoustic tiles on the ceiling - The walls are constructed of sound reflective materials (brick finished with plaster and paint) - Floors are constructed of sound

	reflective materials (concrete and tiles)
Number of learners in the classroom (Motshekga, 2012) - Grades taught in the classroom* - Type of learners in the classroom *	31 learners - Primary school learners between grade one and three. - Mainstream classroom, meaning learners that may have learning difficulties are learning in this classroom.
Desks and chairs *	Each child has their own desk and chair (31) made out of plastic and metal material.
Windows and doors *	There are two big windows across two walls, two facing towards the sports field and two facing towards the corridor. There are no blinds or curtains. - Aluminium framed windows - The glass is 2mm thick One wooden door that is used for entering and exiting.
Location of the classroom	Positioned near a busy road (15m) and a field (5m) where learners play sport during learning time.

	There is also a recreational area located outside of the classroom door. The classroom is located in a row of classrooms and is near the corridor which leads to the field and to more classrooms (please refer to the site plan in Appendix F for an illustration of the position, the classroom is marked with an 'X'. The classroom is located in a two-story building on the ground floor.
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*Measurements were taken from research conducted by Kassuto (2016) with the use of the adapted *Classroom Acoustical Screening Survey Worksheet* by Johnson and Smaldino (2010).

Only one example classroom was used based on the core standards and existing classrooms. One classroom was used for modeling purposes as well as feasibility for the study to encourage buy-in from the participants.

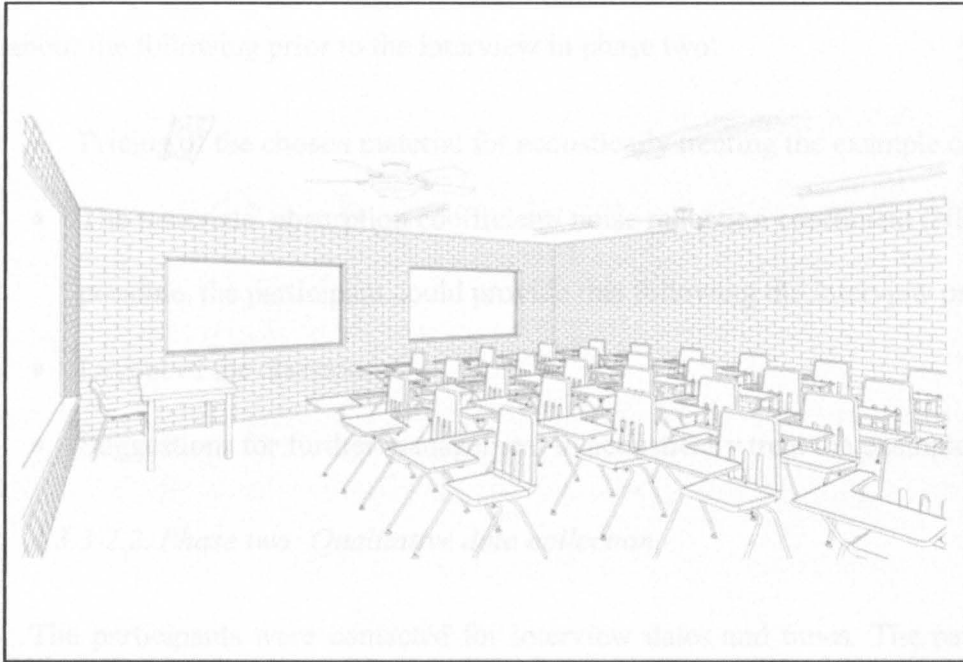


Figure 3.1. Perspective image of the existing example classroom (K. Edery, personal communication, March 8, 2018).

By providing information and images of the classroom, it provided the participant with appropriate expectations of what the research was requesting during phase two. The participants were given the option to prepare in advance or to have a brief overview of the information. By providing the participants with the opportunity to overview the information that was used in phase two it allowed them to be prepared as well as allowed them to understand the process of how the research would move forward. The participants were made aware that they would be requested to make suggestions to acoustically treat the example classroom by using different materials, using different methods, and incorporating their knowledge and skills to acoustically treat the given classroom in the most ideal yet cost-effective way. The participant would need to focus on reducing reverberation times, ambient noise levels, and improving the Speech Transmission Index. Low-cost and effective ways to acoustically treat the classroom were emphasized as the classroom is based in the South

African context where there may be resource constraints. The participants were requested to think about the following prior to the interview in phase two:

- Pricing of the chosen material for acoustically treating the example classroom
- The materials' absorption coefficient/ noise reduction coefficient (NRC) (if possible, the participant could provide this following the interview process).
- Layout of the classroom
- Suggestions for further management to acoustically treat the example classroom.

3.3.3.2.2. Phase two: Qualitative data collection.

The participants were contacted for interview dates and times. The participants and the researcher discussed locations that were convenient for the participants. The researcher endeavoured to ensure that the location fell under ethical guidelines to ensure the research was conducted within an ethical manner. At the interview, the researcher explained the process of the qualitative data collection and the purpose of the study, and the participants were required to read and sign the consent form (Appendix E). The researcher provided 3D representations of the classroom (Appendix G) as well as cross-sections of each wall in the classroom (Appendix G). The participants were requested to roughly draw out their suggestions to acoustically treat the example classroom according to the table of information about the classroom scenario. The participants were asked to verbally label and elaborate on the considerations while they were drawing. This allowed the researcher to obtain an in-depth view of the architects' and acoustic consultants' ideas. This method escaped the linearity of spoken discourse and allowed for the gathering of processes in describing relations of objects, methods, or materials (Theron, Mitchell, Smith, & Stuart, 2011). Drawing as a research tool is often complemented by verbal research methods. This allowed the participants to give voice to what they had drawn (Theron, et al., 2011). This is known as a participatory research

method as this relies on the collaboration between the researcher and the participant to make sense of the drawing via a verbal interview (Theron, et al., 2011). A participative qualitative research method creates an opportunity for a co-construction of meaning, this refers to “collaboratively thinking through text ideas” (Berne & Clarke, 2006, p.675). The researcher and participant engaged in autonomous learning that lead to a co-construction of meaning in classroom acoustics (Lin & Chang, 2014; Hull & Saxon, 2009; Littleton & Whitelock, 2005). The researcher brought unfamiliar information relating to the impact that acoustic conditions can have on learners, the lack of cost-effective solutions, and policy relating to acoustic norms. The participants provided information regarding the low-cost acoustic considerations, concepts, and personal knowledge and experience that they’ve had with acoustics.

During the drawing procedure, the researcher used a semi-structured interview guide (Appendix I) to lead the discussion of the participants’ suggestions drawn on the given classroom frame. Semi-structured interviews can be advantageous as they are flexible enough for the researcher to track emergent themes (Allsop & Saks, 2013). It can also address the ‘why’ and ‘how’ questions from the perspectives of the participants and their subjective experiences (Allsop & Saks, 2013). The combination of drawings and interviewing in qualitative research creates opportunities to obtain information on a setting in a more complete manner (Zweifel & Wezemaal, 2012). It also allows the opportunity for expansion and clarification of the information provided by the participants. This is seen as a more complex way to look into interpretations, suggestions, ideas, and thoughts (Zweifel & Wezemaal, 2012). Drawing is a method that creates reflections which sparks discussions and questions (Zweifel & Wezemaal, 2012). It creates introductions to discuss during the interviews in an explanatory and virtual way (Zweifel & Wezemaal, 2012). Semi-structured interviews were conducted so that the participants could express their answers at their desired length. Semi-structured interviews are used when the researcher prepares a number of

questions in advance to set a general structure for when information needs to be obtained (Drever, 1995). The interviews were conducted in English in which all the participants were proficient; due to the participants having tertiary education, literacy was not an issue that needed to be considered. The semi-structured interview allowed the researcher to be flexible in asking the questions. A funnelling technique was used during the interview process. Funnelling is a three-stage process, asking an open-ended question, probing the participant to funnel the responses into useful information, and closing by summarising and confirming the information that the participant provided (Burnard, 1991; Edwards, 2014). This allowed the participant to add further detail if the information was missed out on and it enabled the researcher to confirm that information provided by the participant was understood appropriately (Burnard, 1991; Edwards, 2014). The questions were formed on the current literature available, and were focussed on areas such as: methods and materials used to reduce reverberation, noise level improvement, STI improvement, layout of the classroom, additional ideas in acoustically treating a classroom, reasons to explain the certain suggestions provided, as well as, general questions based on their experience as professionals in relation to acoustics in classrooms. A digital audio recording device was used for the researcher to be able to transcribe the recorded interview as verbatim responses for analysis. The recordings were downloaded and kept on a password protected computer that only the researcher has access to. The physical drawings were archived in a locked cabinet to which only the researcher and the research supervisors have access to.

3.3.3.2.3. Phase three: Quantitative data collection.

In order to explore the possible effect and benefit of the opinions and suggestions of the architects and the acoustic engineers from phase two, the Sabine reverberation equation was used. The Sabine reverberation equation is exclusive in its outcome as it calculates the reverberation time without the loss of generalization, given that each material's sound

absorption coefficient is provided (Young, 2005). W. C. Sabine created the first approach to describe the reverberation of an enclosure or room in 1900 (Neubauer & Kostek, 2001). This Sabine theory was established on the basis of practical results. Many researchers have contributed to the theoretical basis of calculating reverberation time. Sabine's reverberation theory is still in current use as it is an accurate equation to calculate reverberation time in typical room structures such as rooms that are square or rectangular in shape (Neubauer & Kostek, 2001). Reverberation time is the most important parameter for describing the quality of a room (Neubauer & Kostek, 2001). This parameter was introduced by Sabine in the following equation:

$$RT_{60} = \frac{V}{S} \frac{0.161}{\alpha}$$

V refers to the volume of the room (m^3) which is calculated to be height multiplied by length multiplied by the width of the example classroom which is equivalent to $162.492m^3$, 0.161 is the constant coefficient introduced, S is the total surface area of the material chosen, and α refers to the noise reduction coefficient of the chosen material. All of these parameters calculate the reverberation time according to the materials present in the room. This provides a technical verification of the findings from phase two.

For this study, the equation needed to be adjusted in order to calculate how the original reverberation time had improved or worsened with the acoustic treatments introduced by the participants. The original reverberation time prior to acoustic treatment was 1,4 seconds. Therefore this parameter was placed into the equation to calculate the existing $S\alpha$ in order to determine the reverberation time post-acoustic treatments. This is illustrated as:

$$1,4 = \frac{V}{S} \frac{0.161}{\alpha}$$

Now that the researcher knew what the RT_{60} was, the researcher needed to adjust the equation to calculate what the $S\alpha$ was prior to acoustic treatment. This is important as it provides an accurate reverberation time when using the formula to determine the reverberation time post-acoustic treatment.

$$S \propto = \frac{V 0.161}{1.4}$$

$$S \propto = \frac{26.1614}{1.4}$$

$$S \propto = 18.6867$$

This value represents the classroom's materials surface area and absorption coefficient prior to acoustic treatment. This amount was added into the Sabine formula to calculate the reverberation time post-acoustic treatment as follows:

$$RT_{60} = \frac{V 0.161}{S \propto + 18.6867}$$

This formula calculated the reverberation time post-acoustic treatment while taking into consideration the materials surface areas and absorption coefficients that were present in the classroom prior to acoustic treatment. The new reverberation time indicates how the acoustic treatments have either made an improvement, stayed the same, or worsened the acoustic conditions within the classroom. In order to work out the reverberation time improvement, post-acoustic treatment was subtracted from the reverberation time pre-acoustic treatment.

$$RT \text{ Improvement} = 1.4 - \text{New } RT_{60}$$

The findings from phase two were analysed with the above mentioned Sabine equation and measurements such as reverberation times were measured in a pre- and post-

processing of data. This allowed the researcher to determine in a modelled situation how the acoustics either improved, stayed the same, or worsened. This allowed the researcher to determine which materials are most ideal to use in an existing classroom based on cost and improvement of acoustic properties. Although this is only a modelled scenario it allowed the researcher to determine materials which may work better in the modelled classroom. This may have implications for further research opportunities in placing the most ideal materials found in phase three into a real standing classroom and obtaining measurements regarding the acoustics of the room.

Costing for each material was determined by participants providing cost prices of the selected materials and the researcher obtaining prices from different companies recommended by the participants. Thereafter, the researcher attempted to create a practical and friendly classroom design which obtains the most ideal materials according to improvements in reverberation times, the cost price, as well as the reverberation times, compared to the South African recommended levels of noise and reverberation times for classrooms. This provided an example of a model of how to acoustically treat an existing classroom in the most efficient yet cost-effective way, within the South African context.

3.3.4. Data analysis.

This study used a mixed method approach for data analysis which allowed for the integration of numerical data analysis techniques, thematic data analysis techniques, and analysis techniques that are specific to mixed methods (Tashakkori & Teddie, 2009). This refers to triangulation, when multiple research methods, data sources and collection, analysis strategies, and interpretations occur at the completion of a study and are combined and compared (Tashakkori & Teddie, 2009). The researcher used multiple data sources by using multiple data collection methods, and analysis methods within the data sets and across

methodological paradigms. A mixed method approach can provide a holistic picture of the study at hand. By analysing the qualitative data with the quantitative data, one gets a full picture to understand the issue being researched.

3.3.4.1. Phase one: Qualitative.

The participatory research method was used, therefore, the prepared information was used in the live drawing and semi-structured interview for in-depth analysis and understanding of the motivations for the certain suggestions made.

3.3.4.2. Phase one and two: Qualitative (Member checking, PEI, and Framework thematic analysis).

Once the drawings and semi-structured interviews were completed the researcher transcribed the audio recorded data into text form. The researcher listened to the interviews and typed out the responses of the participants verbatim. This allowed for in-depth analysis of the details of the texts. Each interview was listened to twice to eliminate mistakes within the transcription (Daub, 2009). This also allowed the researcher to limit ambiguity as transcripts can often decontextualize conversations (Daub, 2009). The recorded data were downloaded and stored in a password-protected computer that only the researcher has access to.

Prior to the qualitative data analysis, member checking was conducted with the participants. The data (transcriptions) were returned to the participants to check for accuracy and meaning with their experiences (Birt et al., 2016). This is part of participant validation and will be further discussed in the section 'Rigour' under, 'Issues of Reliability and Validity for Phase Three, and Rigour for Phase Two'.

Following the member checking process, qualitative data analysis was used to analyse the data from phase two. This aimed to bring meaning to the discussion rather than searching for a truth which is usually the aim of quantitative research (Rabbie, 2004). Firstly, analysis

for the drawings with the interview was conducted using the same principles as the photo elicitation interviewing (PEI) analysis technique. Visual data in qualitative research has been commonly used in the last few years (Padget, Smith, Derekjo, Henwood, & Tiderington, 2014). The one approach that has commonly been used is PEI (Collier & Collier, 1986; Harper, 2002; Margolis & Pauwels, 2011; Pink, 2007; as cited in Padget, et al., 2014). PEI provides an alternative to the typical verbal methods of obtaining perceptions. Photos provide a visual record that make the “invisible visible” (Bukowski & Buetow, 2011, p. 739) by eliciting thoughts that need verbalization to be understood by the researcher (Padget, et al., 2014). Adding visual information to verbal information expands the sensory mindfulness that contributes to the holistic understanding of the topic being discussed (Padget, et al., 2014). PEI creates a participatory technique where the participant and researcher are mutually sharing in and focussing on a common interest. PEI involves the use of photos and subsequent interviews that are individualised for each participant (Harper, 2002). This particular study used this technique as the participants would draw on the photos of the example classroom and were interviewed on their designs to elaborate on their thoughts. The researcher controlled the visual ‘media’ used in the study by providing the images of the existing classroom to the participants. This allowed the researcher to have the same scenario for each participant which allowed the participants to express their individual designs for the same scenario. PEI analysis technique was used in this study to provide a visual representation and explanation of the participants’ final designs. The PEI analysis technique was used in addition to Framework Thematic Analysis as the PEI was not detailed enough to portray the complex thought processes of the participants’ designs and the themes that emerged through the semi-structured interview guide.

Following PEI, thematic analysis using the Framework method was used for the data analysis of phase two. Kruger and Casey (2000) highlight that the Framework analysis should

be sequential, verifiable, systematic, and continuous, which paves a path of evidence and increases the dependability of the data which improves the quality of the data. By showing the steps or procedure of the data analysis it increases the rigour of the study (Rabbie, 2004). This was conducted by the researcher and is portrayed within the data collection and analysis chapters of the dissertation.

In order to ensure that the participants' considerations in the data analysis were not weakened, themes in relation to the considerations of the participants were pursued using the Framework analysis method (Richie, Spencer, et al., 2003; Lincoln et al, 2011). Framework analysis is an analytical process which involves five interconnected stages involving, familiarization, identifying a thematic framework, indexing, charting, mapping, and interpretation (Ritchie & Spencer, 1994). Framework analysis is a thematic approach which allows themes to progress from both the research questions and from the research participants' narratives (Rabbie, 2004). This provides structure to the volume of data that was obtained from the semi-structured interviews and allowed the researcher and readers to make sense of the results. It also assisted in finding the most commonly used materials, methods, or other ways of acoustically treating a classroom.

The transcriptions were typed out and were labelled according to the number of the participant, for example, Participant 1 was the heading for the first participant. In order to conduct the analysis of the data, each line of the transcriptions was numbered. The interactions that occurred within the interview were labelled by who was speaking, for example, C represented the researcher, Chantal, and P1, for example, represented the participant number.

3.3.4.3. Phase three: Quantitative (Sabine equation, costing of materials, Wilcoxon paired signed-rank test, and the Pearson product-moment correlation).

Phase three used quantitative data analysis of the numerical data which uses techniques that include the description of the phenomenon of interest (Tashakkori & Teddie, 2009).

The suggestions from phase two were converted into numerical data and placed into the Sabine equation to determine the reverberation time (seconds). This was done as the information needed for the Sabine equation needed to be sought from the qualitative information, such as the suggested material's noise reduction coefficient (NRC). This involved research, conducted by the researcher, regarding the NRC of each material considered. This information was obtained by contacting companies who provide these materials to ensure the NRC values of the materials considered were as accurate as possible. The surface area was calculated by the researcher with the participants' desired measurements of the materials added into the example classroom for acoustic treatment, with the use of a calculator. Reverberation times were calculated post-intervention of acoustic treatments by the researcher. These calculations were discussed with a qualified acoustic engineer who has been practicing in the field for nearly 30 years, this acoustic engineer was not part of the research study. This analysis provided the researcher with an indication of which designs are ideal to use within classrooms, designs that are low-cost yet effective in improving reverberation times. This could provide a model of how to acoustically treat an existing classroom in the most efficient yet cost-effective way within the South African context.

Three analysis techniques were used for phase three. Firstly, descriptive analysis is used when detailed information is needed on the characteristics of an environment (Hootman,

1992). Descriptive analysis is often used as it provides information that cannot always be obtained by analytical means (Hootman, 1992). This was used to describe the pre- and post-acoustic treatment reverberation times and the associated and estimated prices. This could be explained in before-and-after observations, in this case, it could relate to pre- and post-intervention of acoustic treatments and the effect it may have on reverberation times (Shier, 2004).

Secondly, a Pearson product-moment correlation was used to analyse the relationship between post-acoustic treatment reverberation times and the estimated total price for each of the classroom designs. A regression was run using an ANOVA to determine whether this relationship between two variables was significant. The Pearson product-moment correlation coefficient (r) is a linear correlation that is used to find the degree of association of two variables (Jackson, 2012; Paler-Calmorin & Calmorin, 1997). It is very common to use this correlation in order to quantitatively determine if there is a relationship between the two variables (Jackson, 2012; Paler-Calmorin & Calmorin, 1997). The Pearson product-moment correlation coefficient is used to measure a relationship when the data is represented by interval or ratio scales, the variables being correlated do not have to have the same measurable units to be correlated (Lunenburg & Irby, 2008).

Finally, a Wilcoxon paired signed-rank test was used to determine whether there was a significant difference between the pre- and post-acoustic treatment reverberation times. The Wilcoxon signed-rank test for a paired experiment was proposed by Frank Wilcoxon to analyse a paired-difference experiment by looking at the paired differences of two variables (Harry, et al., 2010; Mendenhall, Beaver, & Beaver, 2009; Looney & Hagan, 2015). Wilcoxon signed-rank test is a nonparametric alternative to a paired t-test (Harry, et al., 2010; Looney & Hagan, 2015; Ott & Longnecker, 2010).

3.3.5. Issues of Reliability and Validity for Phase Three, and Rigour for Phase Two

3.3.5.1. Rigour.

Credibility is an internal validity in qualitative methods which involves techniques such as continuous observations as well as triangulation (Marshall & Rossman, 2016; Tashakkori & Teddlie, 2009).

3.3.5.1.1. Phase two.

It is important to consider that interview formats can cause participants to be biased in their responses in order to create a false image for the interviewer (Polgar & Thomas, 2013). The interviewer can also be biased in response to the participants' responses by seeking information that is based on their hypothesis (Polgar & Thomas, 2013). Reliability was ensured by the researcher interviewing each participant with the same questions. However, due to the semi-structured interview which uses a standard set of questions, the researcher could still be flexible in the approach of collecting data. This allowed the researcher to change the sequence of the questions or to probe for more information with secondary questions or seek clarification once the participant had responded (Gratton & Jones, 2010). Reviewing the transcriptions of the interviews multiple times enhanced reliability to correct any mistakes that may have occurred during the transcriptions. Trustworthiness refers to the legitimacy of the data that has been collected and is a common term used when working within qualitative methods (Marshall & Rossman, 2016; Tashakkori & Teddlie, 2009). The interviews were recorded and transcribed verbatim for further analysis so as to lower the the chance of misinterpreting information which can enhance trustworthiness. Member checking was used in phase two, this is also known as participant validation (Klenke, 2008). It is a technique used to explore the credibility of the obtained results (Birt, Scott, Cavers, & Walter, 2016; Klenke, 2008). The data (transcriptions) were returned to the participants to

check for accuracy and meaning with their experiences (Birt et al., 2016) prior to analysis. This heightens the trustworthiness and supports the truthfulness and consistency of the findings of the qualitative results (Speziale, Streubert, & Carpenter, 2011). This allowed the participants to determine the accuracy of the researcher's transcriptions of the semi-structured interviews (Speziale, Streubert, & Carpenter, 2011). The researcher was able to ask clarification questions, where the participant could answer to provide clarity to the researcher (Birt et al., 2016; Speziale, Streubert, & Carpenter, 2011). By conducting member checking it contributes to a participative qualitative research method.

Transferability is also known as external validity when working with qualitative data and methods (Tashakkori & Teddlie, 2009). This refers to the inferences from a certain research setting and the ability of the inferences to be transferred to other similar settings (Tashakkori & Teddlie, 2009). The researcher implemented detailed reports of how the study was conducted in the methodology chapter to ensure that it is replicable. By ensuring rigour, there is a higher chance of the study being able to be replicated. This further made the research and the results which supported it, both valid and reliable.

3.3.5.2. Reliability and validity: Phase three.

Triangulation is used through a mixed method approach, whereby quantitative and qualitative methods are combined to collect and analyse data, therefore providing support to both data sets, the qualitative supports the quantitative data and vice versa. To ensure the improvement of reliability and validity of the data collected, via the interview, the researcher made use of triangulation. The researcher used multiple data sources by using multiple data collection methods, and analysis methods within the data sets and across methodological paradigms. Triangulation was achieved via the mixed method approach of the research. As mentioned previously, triangulation involves the use of multiple independent methods for

data collection which cross-checks that the themes and interpretations emerging from the different methods are matching and consistent (Polgar & Thomas, 2013). This research strategy controls bias and assists in forming conclusions due to the minimum of three different types of methods to collect the data. The researcher used both qualitative (phase two) and quantitative (phase three) research approaches which provided a more diverse perception of the single concept being researched. All data were numerically recorded in the quantitative method and therefore conclusions were made on numerical values and not subjective observations, this improves the reliability and validity of the results. This provides technical verification of the subjective suggestions provided by the participants in phases two and three.

3.4 Chapter Summary

This research study was conducted in a mixed method approach. Following non-medical ethical clearance a pilot study was conducted. The pilot study was conducted in the same process as the main study. Ten participants took part of the study, five being acoustic consultants and five being architects. Data collection took place in three phases: providing information on the study to the participants, conducting a live drawing session (Picture Elicitation Interviewing) and simultaneously conducting a semi-structured interview guide, and lastly, the Sabine reverberation equation was used to calculate the post-acoustic treatment reverberation time. Data analysis was conducted in a mixed method approach. The qualitative analysis included Member Checking, Picture Elicitation Interview analysis, and Framework thematic analysis. The quantitative analysis of the Sabine equation data included the Wilcoxon paired signed-rank test and the Pearson product-moment correlation, as well as, costing of materials used for acoustic treatments. Reliability, validity, and rigour were achieved via triangulation and the mixed method approach of data collection and analysis.

Chapter 4: Results

As discussed previously, the data collection occurred in three phases. The first phase involved information shared via email to each participant that included an information sheet, a consent form, as well as information regarding the process of the research in order to manage expectations from the participant. The second phase of the research consisted of the live drawing of the participants' considerations to acoustically treat the example classroom, as well as the semi-structured interview guide that occurred simultaneously. This phase of the research was recorded with a digital audio recording device. The third phase involved the researcher and the participants' data collected in phase two. The researcher converted the participants' considerations, to acoustically treat the example classroom, into numerical data. This was done by calculating the noise reduction coefficient of each material considered through research via the internet as well as contacting the companies directly who sold the materials. The conversion of the data from phase two also included converting the measurements of each material desired into surface area. This numerical data was used in the Sabine formula for reverberation time. The Sabine formula enabled the researcher to calculate whether the reverberation time improved, stayed the same, or worsened following the considerations provided from the participants in phase two.

Within phase one and two of the results section, the researcher refers to 'domains', 'dominant themes', and 'subthemes' when discussing the tables that contain the participants' responses from the semi-structured interviews. The term 'domains' referred to the general category that represented the information in the table, for example, acoustic treatment suggestions to improve reverberation time. Following the domain, there were 'dominant themes' that emerged from the data, this further categorised the data into more specific categories, for example, acoustic treatment of the ceiling. The researcher found, that each dominant theme had further 'subthemes' that made reading and understanding the data easier.

The ‘subtheme’ referred to the different categories that fell under the ‘dominant theme’, for example, acoustic ceiling tiles versus another ‘subtheme’ of acoustic ceiling islands. The researcher referred to Appendix H, this appendix contains detailed excerpts from the semi-structured interviews. The tables included in the qualitative results sections are example excerpts that represent each subtheme. This was utilised throughout the results section.

4.1. Phase One of Data Collection and Analysis

4.1.1. Qualitative: Live drawings of the participants’ considerations to acoustically treat the example classroom with the simultaneous semi-structured interview.

This section answered the first secondary objective of the research. The participants were given images (Appendix E) that represented the example classroom, this consisted of cross-sections, perspective images, as well as 3D representations of the example classroom. Within this section, there is reference to the participants’ responses from the semi-structured interviews, the detailed excerpts examples can be located in Appendix H. The image pack included a table that contained information about the example classroom, for example, the current reverberation time, ambient noise level, location of the example classroom, and number of learners in the example classroom. The participants were given time to think about the different considerations they had and were then asked to draw out their considerations on the images that represented the areas that they desired to acoustically treat. While the participants were drawing out their considerations to acoustically treat the example classroom, they simultaneously participated in a semi-structured interview guide that consisted of eight open-ended questions.

4.1.1.1. *Picture Elicited Interview (PEI) analysis.*

The first step in the analysis for phase two, that included the drawings with the semi-structured interview, was conducted using the same principles as the picture elicitation interviewing (PEI) analysis technique. PEI analysis technique was used in this study to provide a visual representation and explanation of the participants’ final designs. This analysis section is introductory and only illustrates the participants’ final internal acoustic treatment design. The Framework thematic analysis goes into more detail of the participants’ thought processes and designs following the PEI analysis technique.

4.1.1.1.1. *Participant 1*

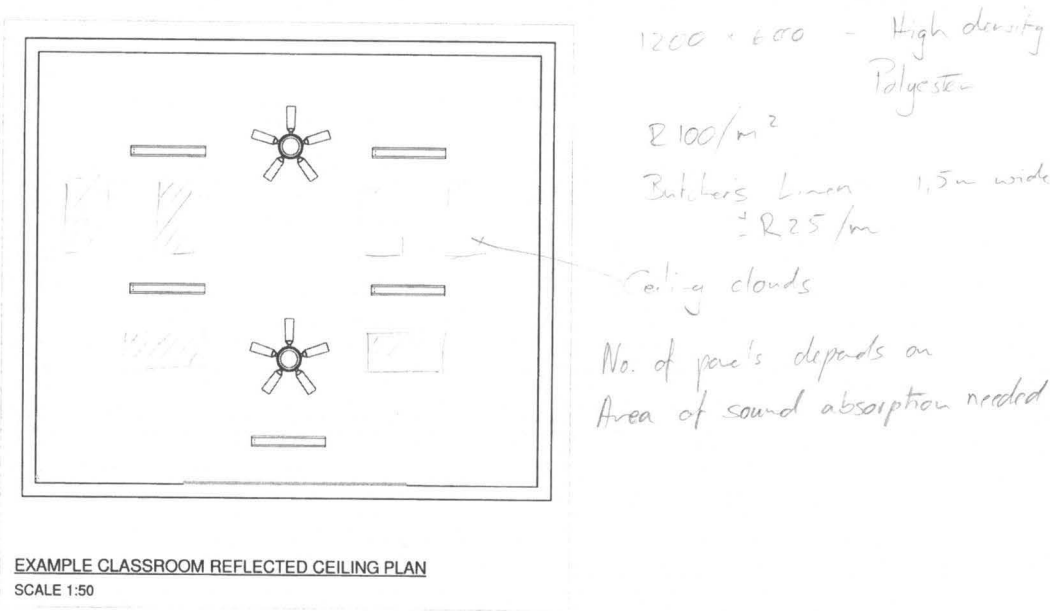


Figure 4.1. Example classroom reflected ceiling plan.

Referring to Figure 4.1. and Table 2 (Appendix H) under the dominant theme ‘Acoustic treatment of the ceiling’, Participant 1 designed a low-cost solution to introducing absorption onto the ceiling. The participant chose to implement cloud absorption panels that hang from the ceiling. The participant mentioned that the absorption panels should be placed

over the learners’ heads so that if the learners were generating noise it would be directly absorbed by the panels above them. Participant 1 opted for home-made panels to ensure cost was kept to a minimum by using high-density polyester fibre, a timber frame, and butchers linen to cover the panel.

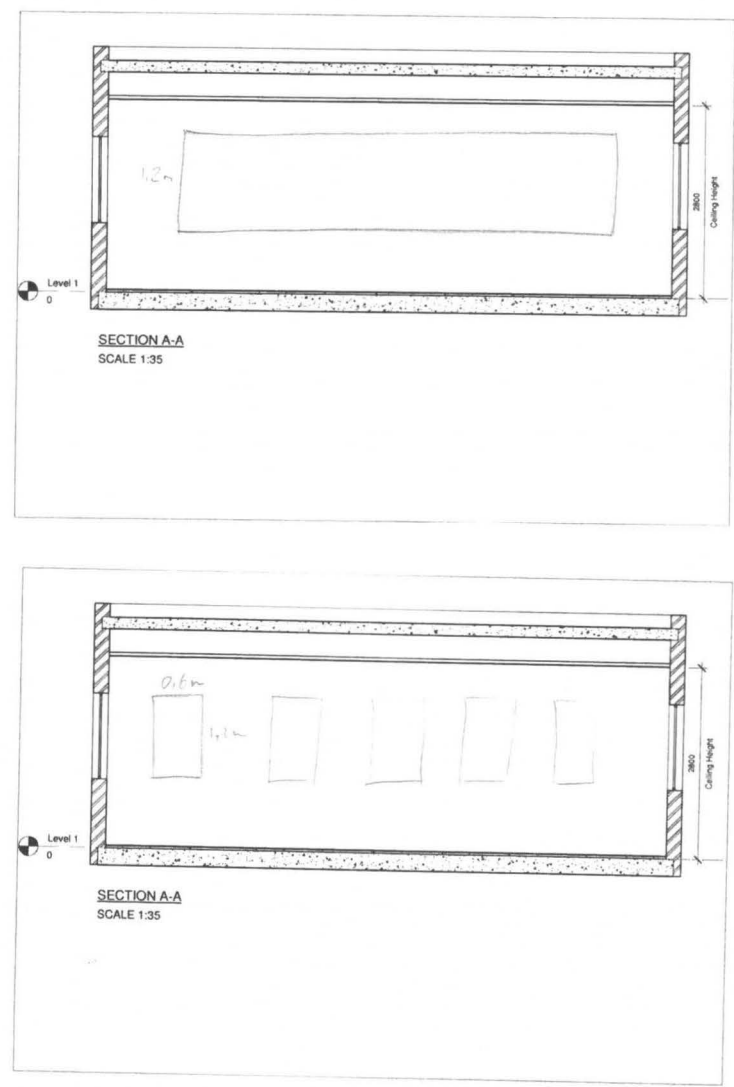


Figure 4.2. Cross-section of the back wall in the example classroom.

Referring to Figure 4.2. and Table 2 (Appendix H) under the dominant theme ‘Acoustic treatment of the back wall’ Participant 1 opted for another home-made solution to implement on the back wall of the example classroom. The back wall panels are made by the

same technique as the cloud absorption panels on the ceiling, high-density polyester fibre, in a timber frame, and covered by butcher's linen.

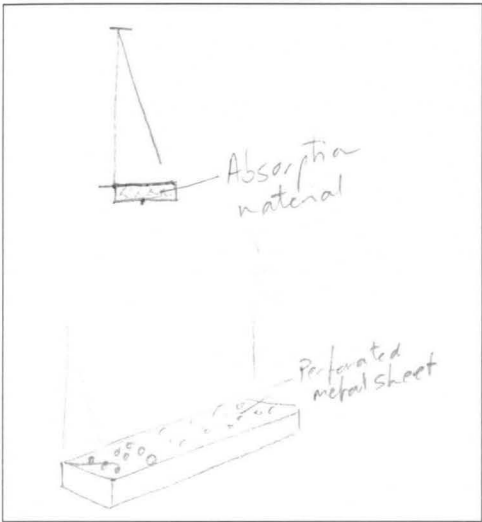


Figure 4.3. A custom made absorption panel to be implemented outside the windows in the example classroom.

Referring to Figure 4.3. and Table 4 (Appendix H) under the dominant theme of ‘Custom made absorption panel’, Participant 1 designed a structure that would fit underneath the window on the outside of the classroom. This structure would be made of perforated metal to create a box-like structure with polyester fibre inside to create absorption for the sound that attempts to enter the classroom.

Participant 1 designed other elements that were not illustrated on an image, such as introducing a carpet in the front of the classroom where the teacher would stand to increase sound absorption in the classroom. The participant also suggested adding plexiglass to the windows to increase the thickness of the glass to reduce the ambient noise level in the classroom.

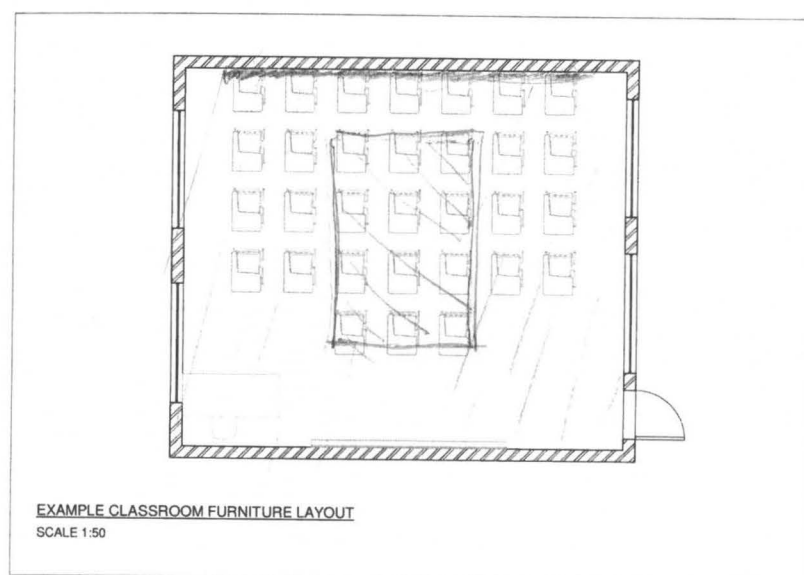
4.1.1.1.2. Participant 2

Figure 4.4. Example classroom furniture layout to illustrate Participant 2 acoustic treatment ceiling plan.

Referring to Figure 4.4. and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the ceiling’, Participant 2 opted for treating the ceiling with acoustic tiling. Participant 2 emphasised that covering 100% of the ceiling would immediately bring the reverberation time to an appropriate level. As seen in Figure 4.4 there is a box-like drawing in the middle of the ceiling. The participant was showing the different options of acoustically treating the ceiling according to what was needed in the classroom. Participant 2 mentioned that a suspended grid drop-in tile would be much cheaper than implementing many different options of absorption into the classroom. Participant 2 concluded that by covering the entire ceiling in Class C (NRC of 0.7) acoustic ceiling tiles the reverberation time would improve to an appropriate level that would improve the listening environment for the learners.

4.1.1.1.3. Participant 3

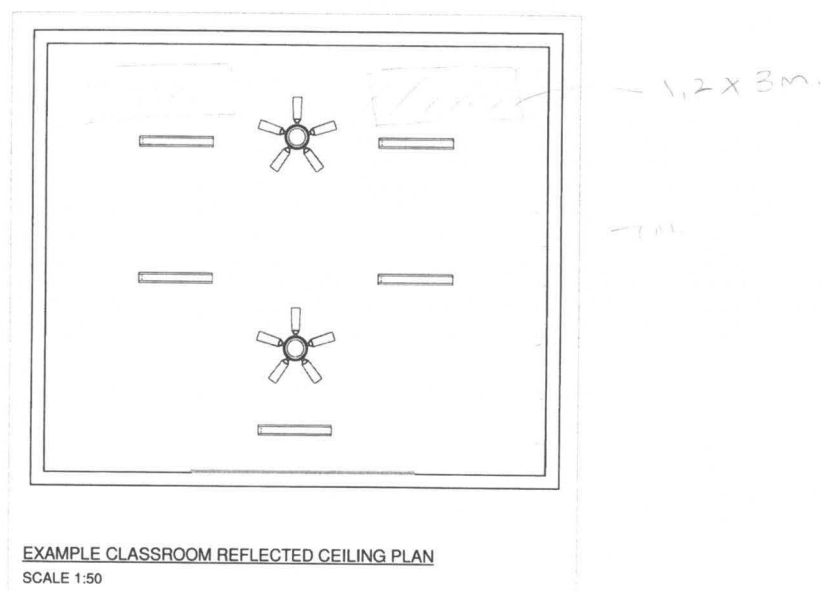


Figure 4.5. Example classroom reflected ceiling plan illustrating Participant 3 design.

Referring to Figure 4.5. and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the ceiling’, Participant 3 chose to implement acoustic ceiling islands, much like the cloud absorption panels that Participant 1 suggested. Participant 3 suggested that the islands should be positioned at the back of the classroom as it would minimize the echo and feedback of the sound reflection which essentially improves the reverberation time in the classroom. These islands would be home-made, composed of a timber frame, polyester fibre, and fabric to cover the structure. The participant mentioned that this is a non-invasive procedure as the islands can be suspended off the existing ceiling.

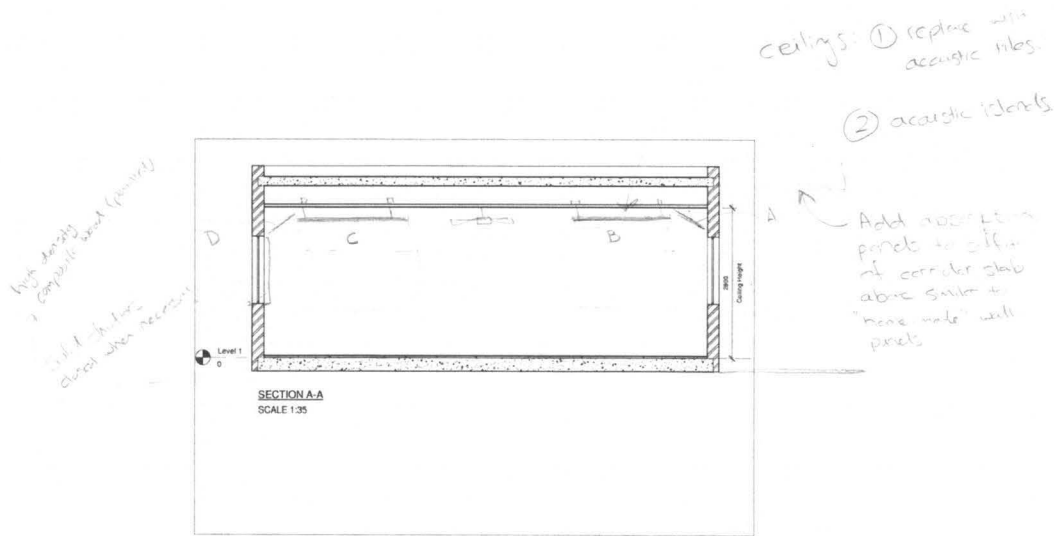


Figure 4.6. A cross-section of the back wall to illustrate the acoustic ceiling island placements off the existing ceiling.

As illustrated in Figure 4.6., the islands (labelled B and C in the drawing) would be suspended off the ceiling in the desired position. The participant also mentioned that there should be islands on the corners of the back wall ceiling (labelled A and D in the drawing) as disturbing echoes often originate where a vertical and a horizontal line meet.

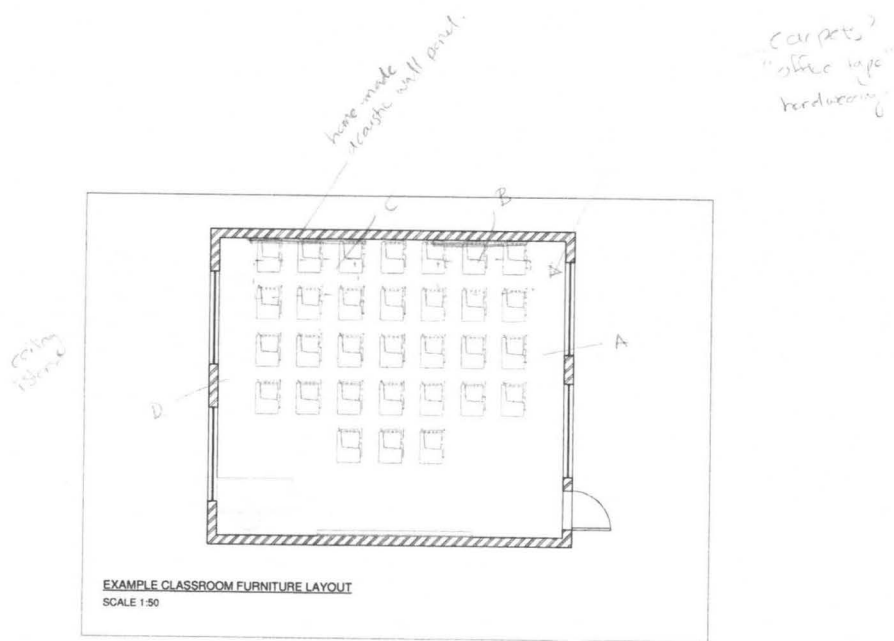


Figure 4.7. Example classroom furniture layout illustrating the placement of the back wall absorption panels and carpet layout.

Referring to Figure 4.7. and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’, Participant 3 recommends that there should be absorptive panels on the back wall, since the windows are on the side wall and the blackboard is in the front, the only wall that provides opportunity for adding absorption is the back wall. Participant 3 opted for carpets in reading areas to increase the amount of absorption in the classroom. The participant mentioned that the carpet should be hardwearing such as those in an office, as this will improve the ease of maintenance.

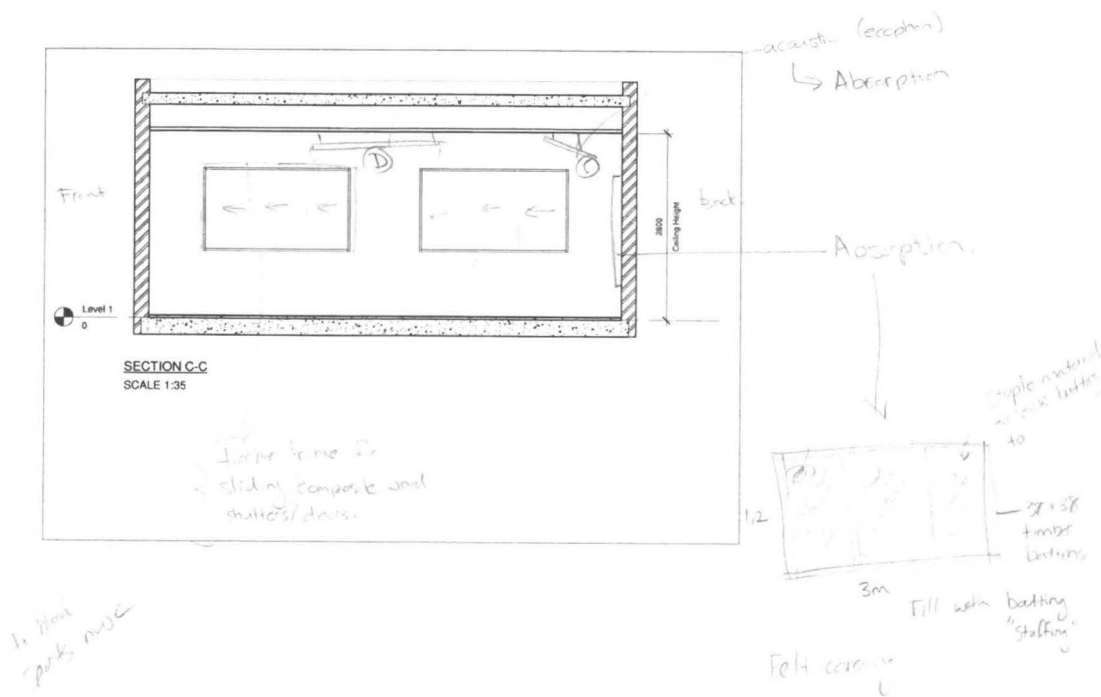


Figure 4.8. A cross-section of the side wall to illustrate the participant’s sliding wooden shutters.

Referring to Figure 4.8. and Table 3 (Appendix H) under the dominant theme of ‘Shutters/curtains’, Participant 3 illustrates the design of wooden shutters that can be home-made. According to Participant 3, the wooden shutter's purpose is to reduce sound coming from outside into the classroom. This mechanism would be made of three sliding panels that slide over each other. According to Participant 3, the sliding mechanism was designed so that there would still be ventilation and light can still enter in the classroom by having one or two of the elements stacked up.

4.1.1.1.4. Participant 4

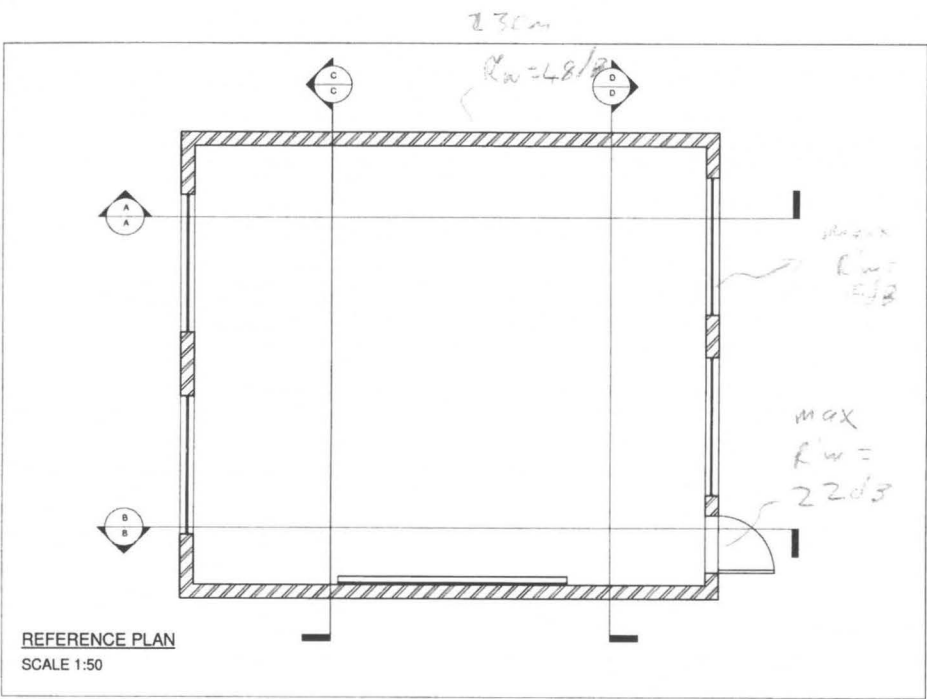


Figure 4.9. Reference plan used for Participant 4's illustration.

Referring to Figure 4.9. it is observed that Participant 4 preferred to talk through the design than draw it. The measurements seen on Figure 4.9. refer to the materials ability to isolate sound, the participant shows the isolation ability through decibel reduction of the wall, the windows, and the door. Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the ceiling’, Participant 4 opted for covering the entire ceiling with a Class C acoustic ceiling tile with an NRC of 0.7. Participant 4 mentioned that the original ceiling would need to be removed and a drop-in suspended grid ceiling would need to be introduced with the acoustic ceiling tiles. The participant emphasised that by treating the entire ceiling it would be the most functional and effective step for improving the internal acoustic quality.

Referring to Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’, Participant 4 spoke about the importance of introducing absorption onto the back wall. However, Participant 4 also mentioned that due to limited resources this treatment

should come secondary to the acoustic ceiling treatment. The participant mentioned that the back wall panels can be made by a local contractor by using a timber frame, polyester fibre, and covered by a fabric finish. Referring to Table 2 (Appendix H) under the dominant theme of 'Replacing fans', the participant emphasised the importance of replacing the old fans with new fans as it caused increased noise levels in the classroom.

According to Participant 4 calculations, it was concluded that these were the three designs and considerations to be used in the example classroom setting, especially due to the limited resources that need to be considered.

4.1.1.1.5. Participant 5

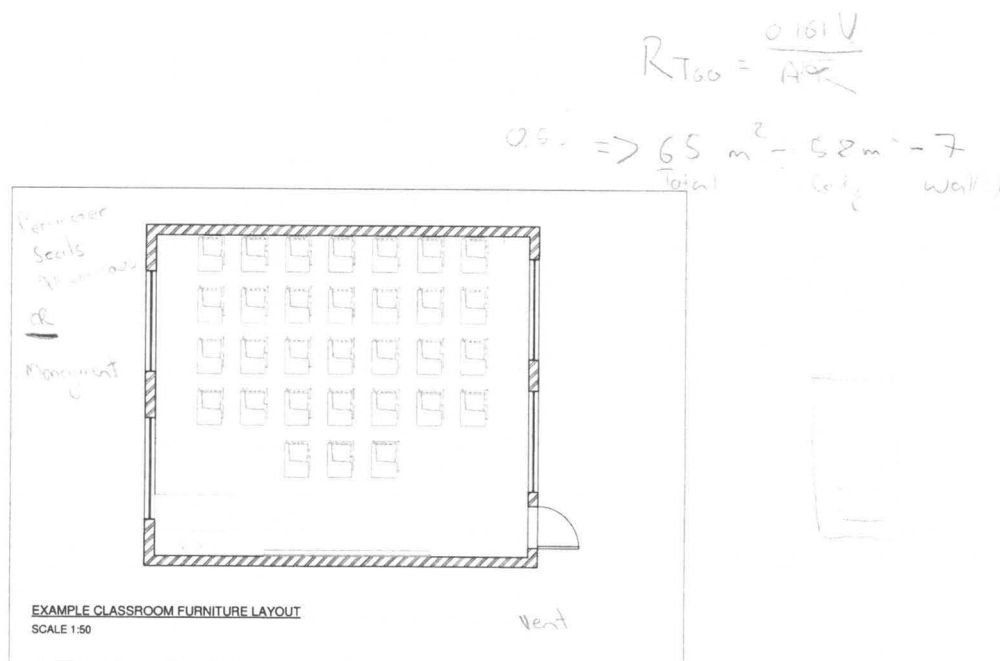


Figure 4.10. The example classroom furniture layout that Participant 5 used to illustrate the acoustic treatment design based on the Sabine formula.

Participant 5's approach to acoustically treating the classroom was based on using the Sabine formula to calculate how much absorption was needed to be added into the classroom in order to achieve an appropriate reverberation time. Figure 4.10. illustrates a variation of the Sabine formula used to calculate exactly how much surface area of absorption was needed

to be introduced into the classroom in order to reduce the reverberation time to an appropriate time. As seen in Figure 4.10. on the left side of the drawing and referring to Table 3 (Appendix H) under the dominant theme of ‘Windows and doors’, Participant 5 mentioned the use of seals, such as, neoprene rubber seals on the windows to improve on sound insulation when the windows are closed. The participant also mentioned that the school could implement management plans to ensure that noise from the recreational area and sports field is kept to a minimum. On the bottom left of Figure 4.10., the word ‘vent’ is written, this refers to a vent that could be placed onto the existing door to improve ventilation if the door needs to be closed due to external noise disturbances. This vent on the door is drawn on the right side of Figure 4.10. and the description can be found in Table 3 (Appendix H) under the dominant theme of ‘Windows and doors’.

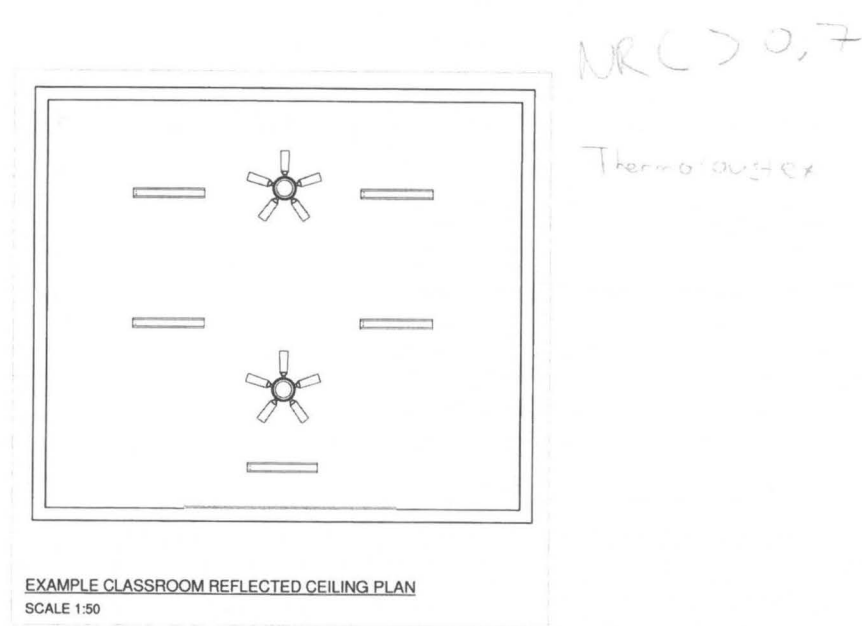


Figure 4.11. The example classroom reflected ceiling plan, illustrating Participant 5’s design for the acoustic treatment of the ceiling.

Referring to Figure 4.11 and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the ceiling’, Participant 5 emphasised the importance of covering as much of the ceiling as possible. Participant 5 suggested that instead of removing the original

ceiling one could stick the acoustic ceiling tiles directly onto the existing ceiling so that the procedure is non-invasive and quicker to implement. Participant 5 suggested the use of polyester fibre ceiling tiles as they are cheaper.

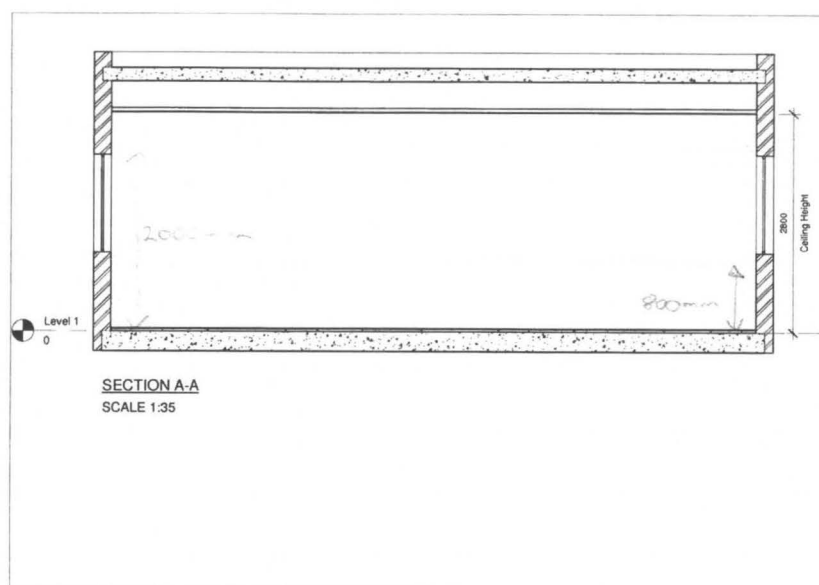


Figure 4.12. A cross-section of the back wall of the classroom.

Referring to Figure 4.12 and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’, Participant 5 mentioned the importance of implementing acoustic panels on the back wall to improve the reverberation time and speech transmission.

Participant 5 concluded that treating the entire ceiling, the back wall, placing seals on the windows, placing a vent on the door, and keeping external noise to a minimum via management was the most low-cost and effective design to acoustically treat the existing classroom.

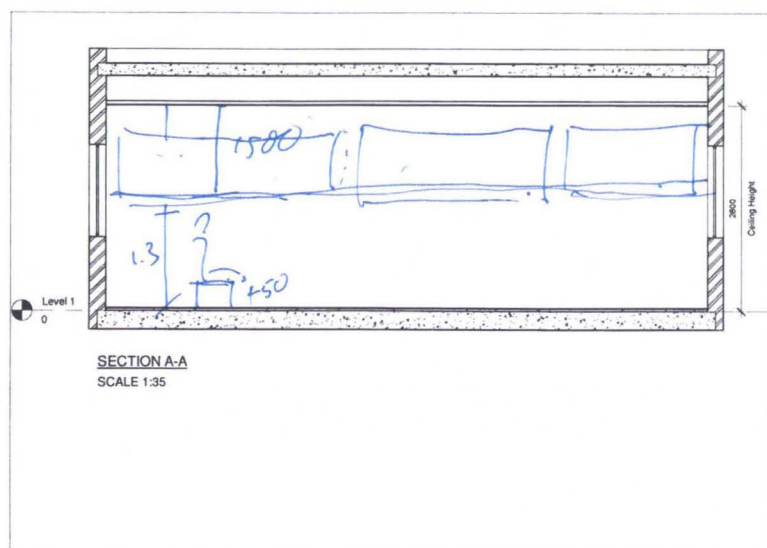
4.1.1.1.6. Participant 6

Figure 4.13. A cross-section of the back wall of the example classroom.

Referring to Figure 4.13 and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the ceiling’, Participant 6 expressed that even though it is more expensive to implement an acoustic ceiling it would improve the internal acoustic conditions. As seen in Figure 4.13, the participant has drawn acoustic panels on the back wall. In Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’, Participant 6 mentioned using cork for the back wall panels, covered in felt fabric so that it has a dual function of absorbing sound reflections as well as functioning as a pin board. Participant 6 also mentioned placing egg crates on the back wall to assist with sound absorption, and positioning them inbetween the cork panels. The participant mentioned in Table 2 (Appendix H) under the dominant theme of ‘Curtains’ that it would be recommended to hang the

learners' artwork off the ceiling in order to absorb sound that may be reverberating in the classroom, this is illustrated by the free-hand drawing on the right side of Figure 4.13.

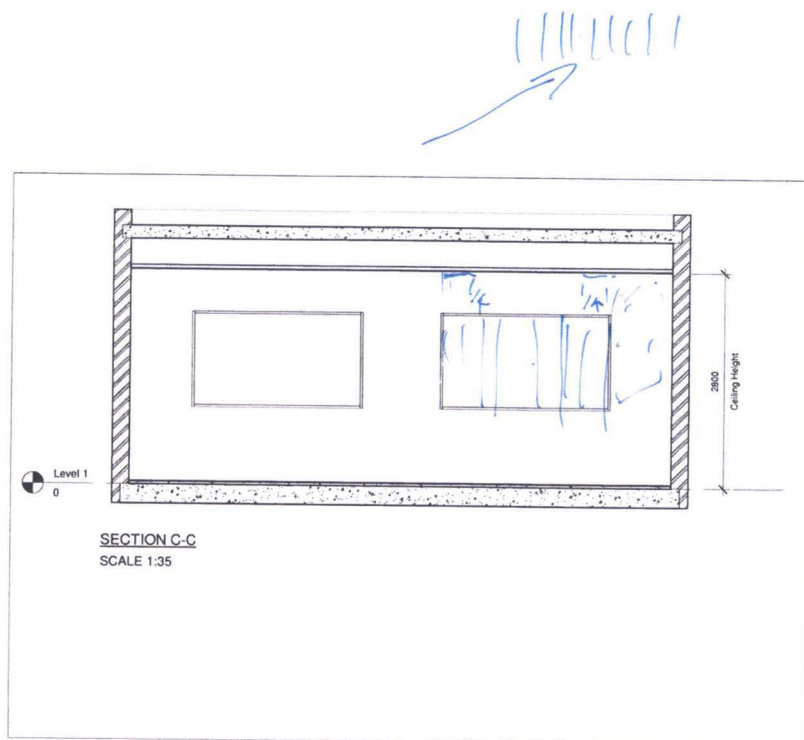


Figure 4.14. A cross-section of the side wall, with windows, of the example classroom.

Referring to Figure 4.14 and Table 3 (Appendix H) under the dominant theme of ‘Curtains’, Participant 6 suggested that curtains are good for absorbing sound even though they are not a traditional addition to have in a classroom. The participant mentioned that the curtains should go all the way up to the ceiling and stop right below the window. The participant also mentioned that the curtains can be left open to a quarter on either side of the window to ensure light does not become an issue.

4.1.1.1.7. Participant 7

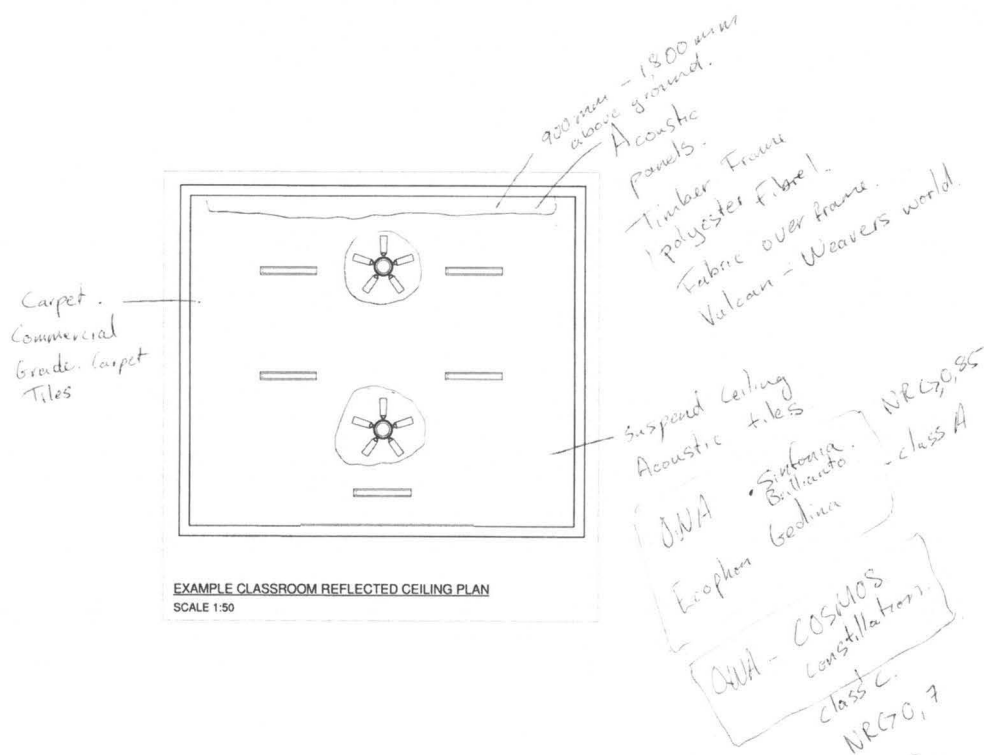


Figure 4.15. The example classroom furniture layout.

Referring to Figure 4.15 and Table 2 (Appendix H) under the dominant theme of ‘Prioritise acoustic treatment for reverberation time’, Participant 7 expressed that the cheapest way to improve reverberation time by introducing absorption is on the ceiling. Participant 7 mentioned that the cheapest way to do this is by suspending a ceiling with acoustic tiles. Referring to Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the ceiling’, the participant would use Class C (NRC of 0.7) on the ceiling to reduce the reverberation time to around 0.6 seconds. Referring to Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’ Participant 7 suggested that acoustic panels on the back wall are important for sound absorption and can be done cheaply by making them out of a timber frame, polyester fibre, and covering the structure with fabric. Referring to the right side of Figure 4.15 and Table 2 (Appendix H) under the dominant theme of ‘Carpets/flooring for reverberation absorption’ Participant 7 expressed that the

whole floor should be carpeted. The participant mentioned that the carpet will not do much for the reverberation time but it still introduces soft textures into the classroom that acts as absorption.

Referring to Table 2 (Appendix H) under the dominant theme of ‘Curtains’ Participant 7 shared an interesting fact that was discovered when undergoing a project in a school. The participant explained that the curtains introduced into a classroom are not necessarily what’s improving the acoustics, but rather the air-gap between the curtain and the window. From the participant’s experience, this did make an improvement in the reverberation time and therefore suggests that it would be beneficial to introduce into the example classroom design.

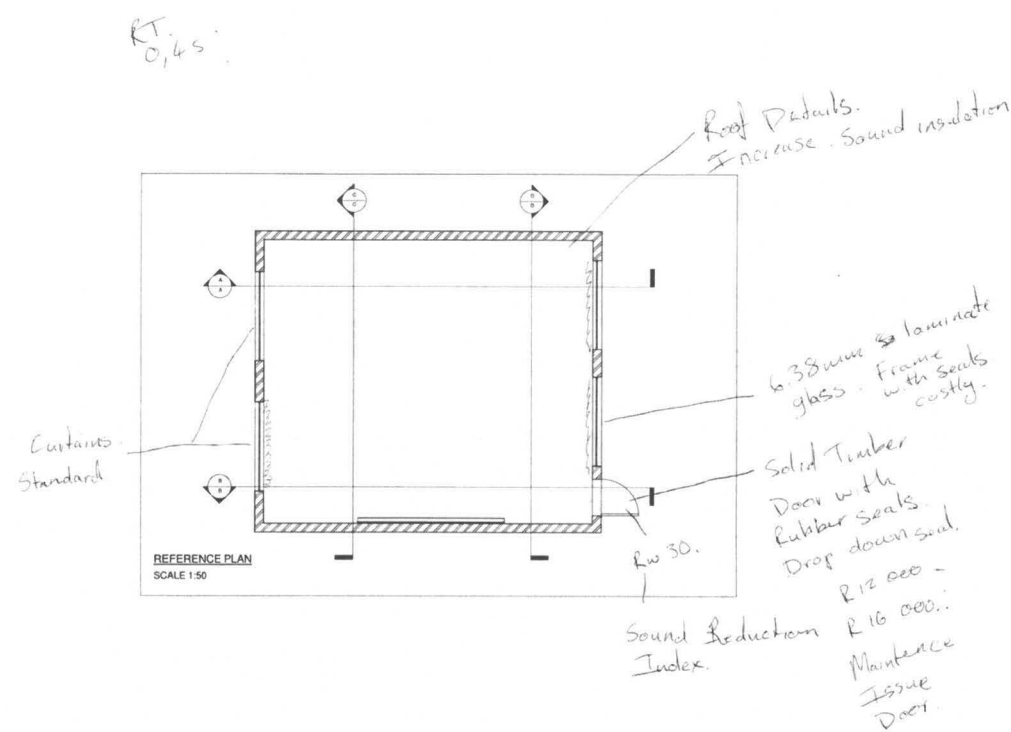


Figure 4.16. The aerial view reference plan of the example classroom.

Referring to Figure 4.16 and Table 3 (Appendix H) under the dominant theme of ‘Windows and doors’, Participant 7 mentioned that the door should ideally be changed to a

solid timber door, however, this is very expensive and therefore the participant mentioned that rubber seals on the door would assist with sound isolation once it is closed.

4.1.1.1.8. Participant 8

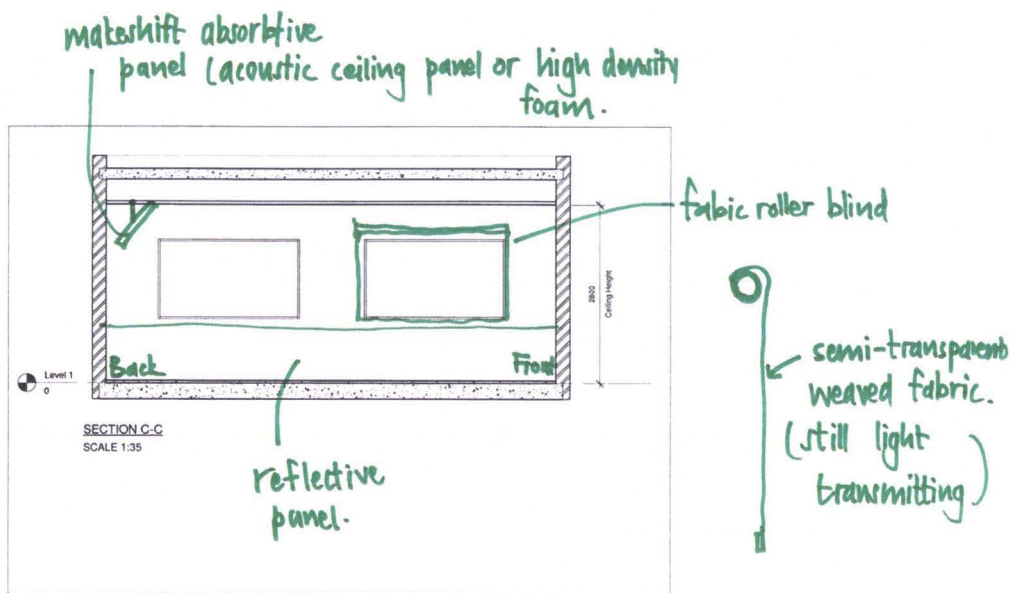


Figure 4.17. Cross-section of the side wall in the example classroom, showing the windows.

Referring to Figure 4.17 and Table 2 (Appendix H) under the dominant theme ‘Acoustic treatment of the ceiling’, Participant 8 reported that the whole ceiling should be covered in acoustic ceiling tiles made of gypsum. Looking at Figure 4.17 and Table 2 (Appendix H) under the dominant theme of ‘Curtains’, Participant 8 mentioned that semi-transparent roller blinds could be placed on the windows so that it does not limit light coming into the classroom.

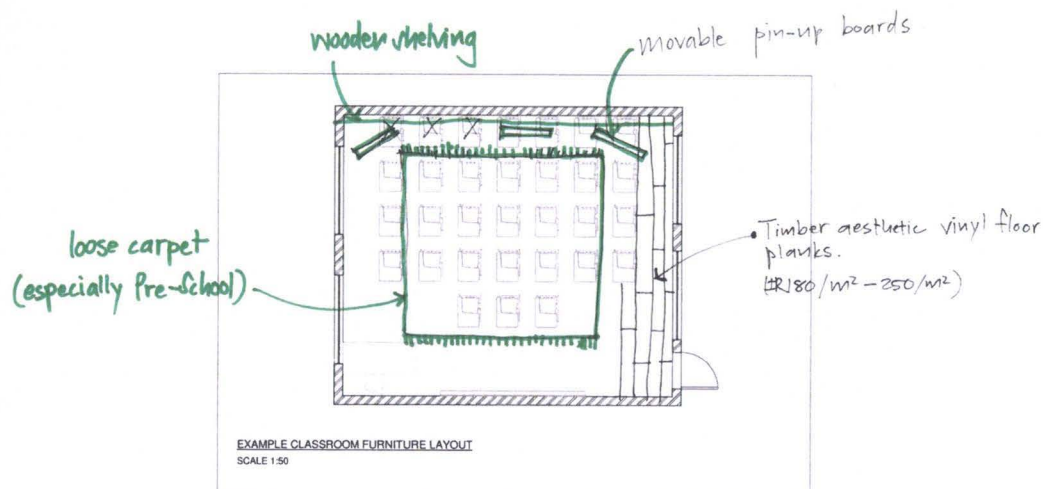


Figure 4.18. The example classroom furniture layout.

Referring to Figure 4.18 and Table 2 (Appendix H) under the dominant theme of ‘Carpets/flooring for reverberation absorption’, Participant 8 recommended using a loose carpet to create a soft floor finish. The participant mentioned that the carpet is functional at a foundational level, as the learners often sit on the floor to play or read. In Table 2 (Appendix H) under the dominant theme of ‘Shelving and other absorptive furniture’, Participant 8 mentioned introducing shelving and other natural material elements to increase soft surfaces for absorption.

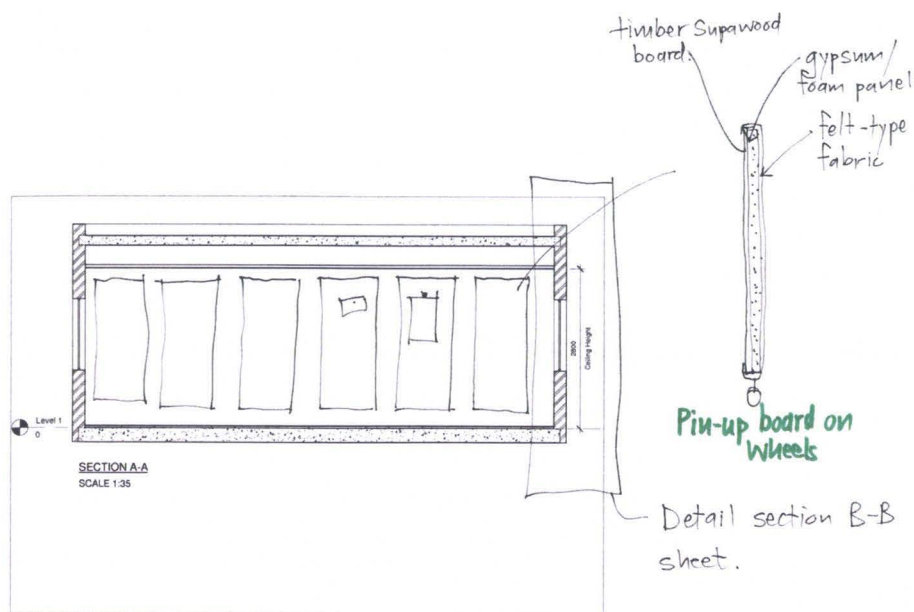
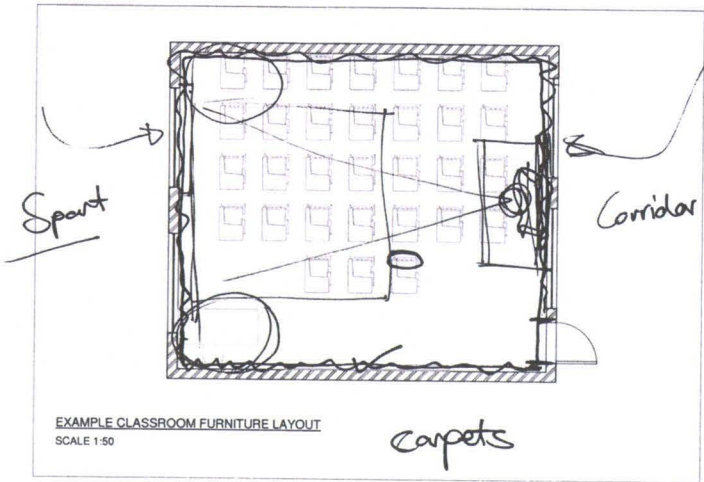


Figure 4.19. A cross-section of the back wall of the example classroom.

Referring to Figure 4.19 and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’, Participant 8 suggested creating a pin-up board made from a timber frame, foam, and covered in felt. The participant suggested that this absorption panel should be placed on wheels so that it can be moved around easily to wherever it is needed.

4.1.1.1.9. Participant 9



6 off
Bean bags

Figure 4.20. The furniture layout of the example classroom.

Referring to Figure 4.20 and Table 2 (Appendix H) under the dominant theme of ‘Carpets/flooring for reverberation absorption’, Participant 9 spoke about introducing loose carpets into the classroom as it is a cheaper application. In Table 2 (Appendix H), under the dominant theme of ‘Curtains’ Participant 9 talks about introducing curtains onto the windows in order to improve the reverberation time in the classroom. As seen in Figure 4.20, the participant chose to implement six bean bags into the corners of the rooms to increase absorption into the classroom with functional use. In Table 2 (Appendix H) under the dominant theme of ‘Shelving and other absorptive furniture’, the participant spoke about bean bags as well as chair bags that would introduce a soft touch to the chairs in the classroom that both aid in the reduction of the reverberation time. An important factor that Participant 9 discussed was the rearrangement of the classroom, this can be seen in Figure 4.20 and in Table 3 (Appendix H) under the dominant theme of ‘Rearrangement of the classroom’. The main treatment option that Participant 9 suggested was the rearrangement of the classroom. This included moving the learners’ desks to face the wall that had the door, causing their backs to be facing the sports field, represented in Figure 4.20. The participant expressed that this would mean moving the blackboard to the front of the windows that would reduce the expected visual distraction.

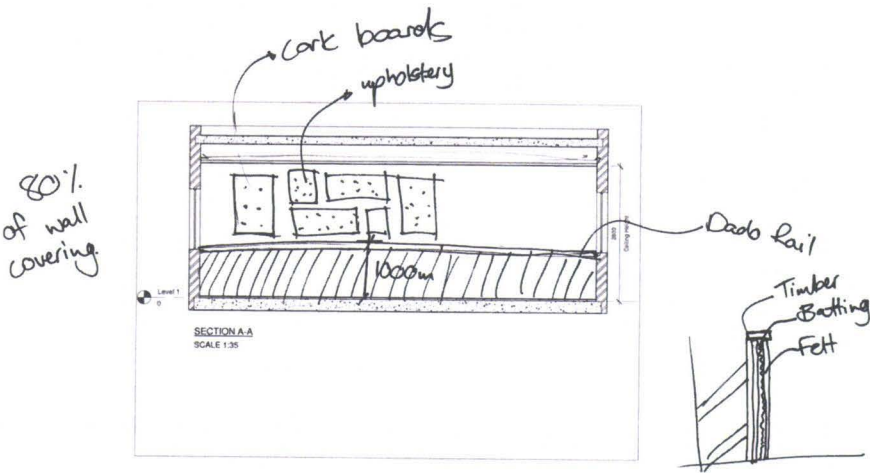


Figure 4.21. A cross-section of the back wall of the example classroom.

Referring to Figure 4.21 and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’, Participant 9 explained the idea of a dado rail. As seen in Table 2 (Appendix H), the participant explained that a dado rail is a term used to describe a pin-up area that extends across the whole wall but only at one meter high. According to the participant the dado rail would be made up in the same way as a headboard, a timber frame, and upholstery material. The participant also mentioned covering 80% of the back wall with cork panels, illustrated in Figure 4.21, that can be in different sizes and shapes and could be used functionally for the teacher to pin-up relevant posters.

4.1.1.1.10. Participant 10

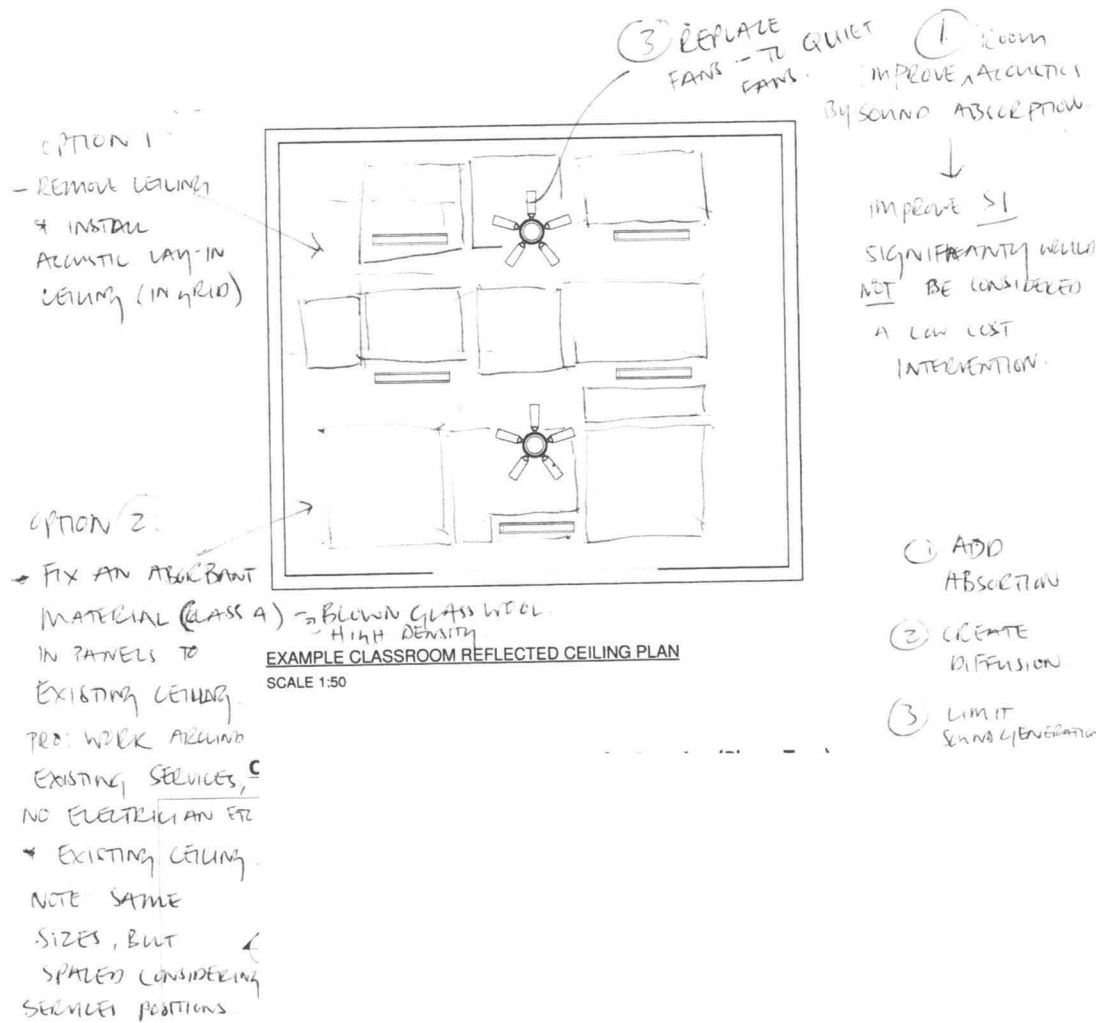


Figure 4.22. The example classroom reflected ceiling plan.

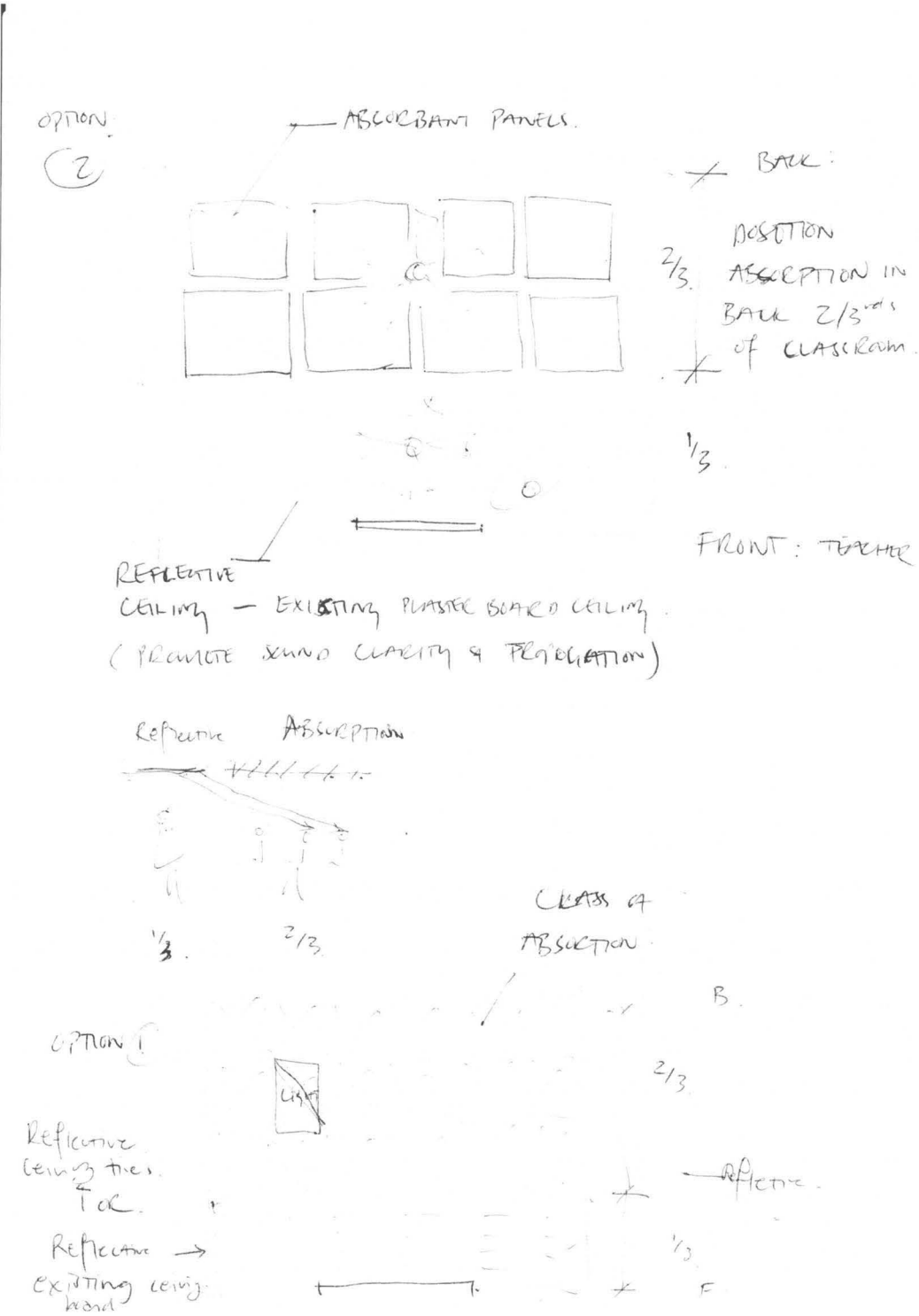


Figure 4.23. Free-hand drawing of the participant's options to acoustically treat the ceiling.

Referring to Figures 4.22 and 4.23, and Table 2 (Appendix H) under the dominant theme of 'Acoustic treatment of the ceiling', Participant 10 illustrated the two different

options of acoustically treating the ceiling. Option one was, removing the original ceiling and covering 100% of the ceiling in acoustic ceiling tiles as illustrated in Figure 4.22, and option two being, covering the back two-thirds of the ceiling in absorptive acoustic ceiling tiles or acoustic panels (Figure 4.23 option one and two) and leaving the front one-third of the ceiling with the original ceiling or covering it in reflective ceiling tiles. The participant chose option two, covering two-thirds of the classroom and leaving one-third exposed. The participant illustrated the chosen strategy in Figure 4.23 by showing a teacher and how the voice is projected to the learners by having the one-third and two-third acoustic ceiling strategy. This picture in Figure 4.23 illustrated the reflective ceiling above the teacher assists to promote the speech signal and assists with absorption in the back two-thirds where the learners are located.

Referring to Figure 4.22 and Table 3 (Appendix H) under the dominant theme of ‘Replacing fans’, Participant 10 mentions that replacing the fans is important as the current ones make excess noise that affects speech clarity. According to the participant the fan is also needed as it provides fresh air supply especially when the windows and door may be closed due to external noise sources.

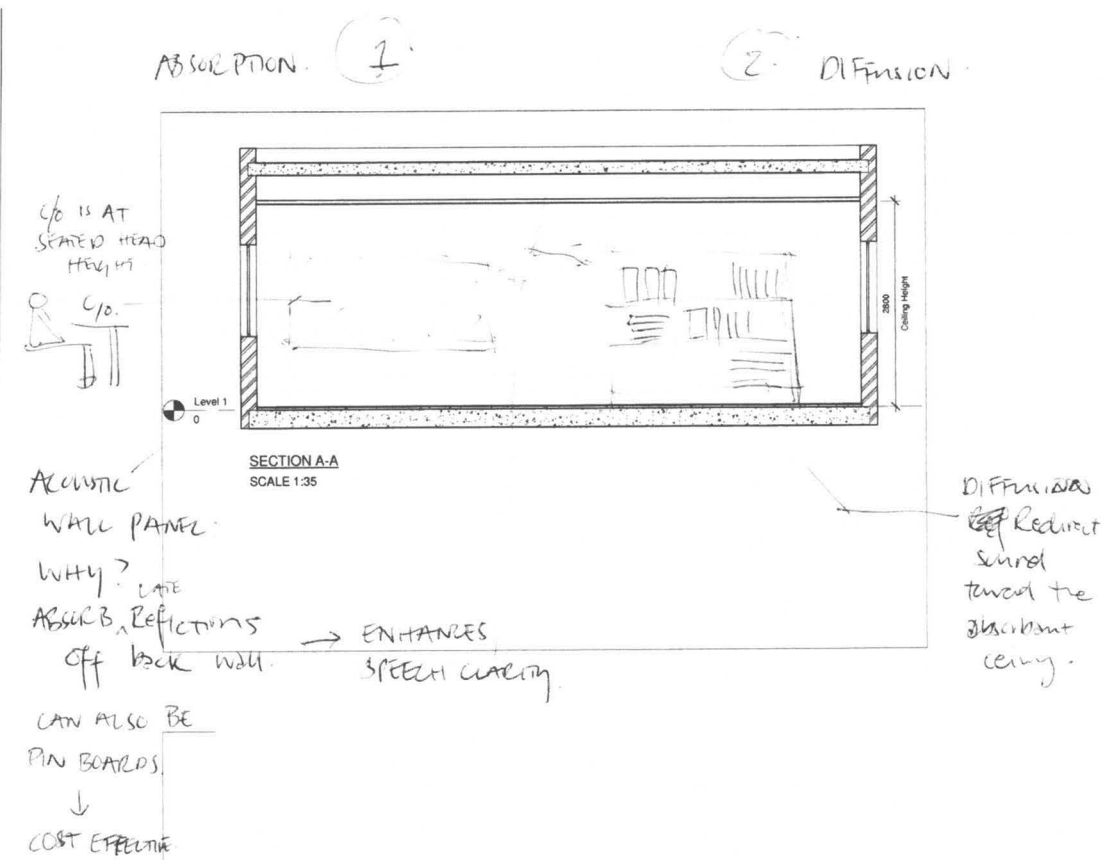


Figure 4.24. Cross-section of the back wall of the classroom.

Referring to Figure 4.24 and Table 2 (Appendix H) under the dominant theme of ‘Acoustic treatment of the back wall’ Participant 10 spoke about introducing back wall acoustic panels to absorb any late reflections that could essentially improve speech clarity, as written in Figure 4.24. The participant mentioned that materials added to the classroom need to work hard and have more than one function. The participant explained that the back wall panels could double up as pin-up space that are functional in a classroom setting. Participant 10 also mentioned the use of using furniture to diffuse the sound energy (Table 2 (Appendix H) under the dominant theme of ‘Shelving and other absorptive furniture’). The participant specifically spoke about bookshelves on the back wall, as seen in Figure 4.24, this helps with

sound diffusion towards the ceiling to be absorbed. This sound diffusion towards the ceiling provides the ceiling function with maximum capacity.

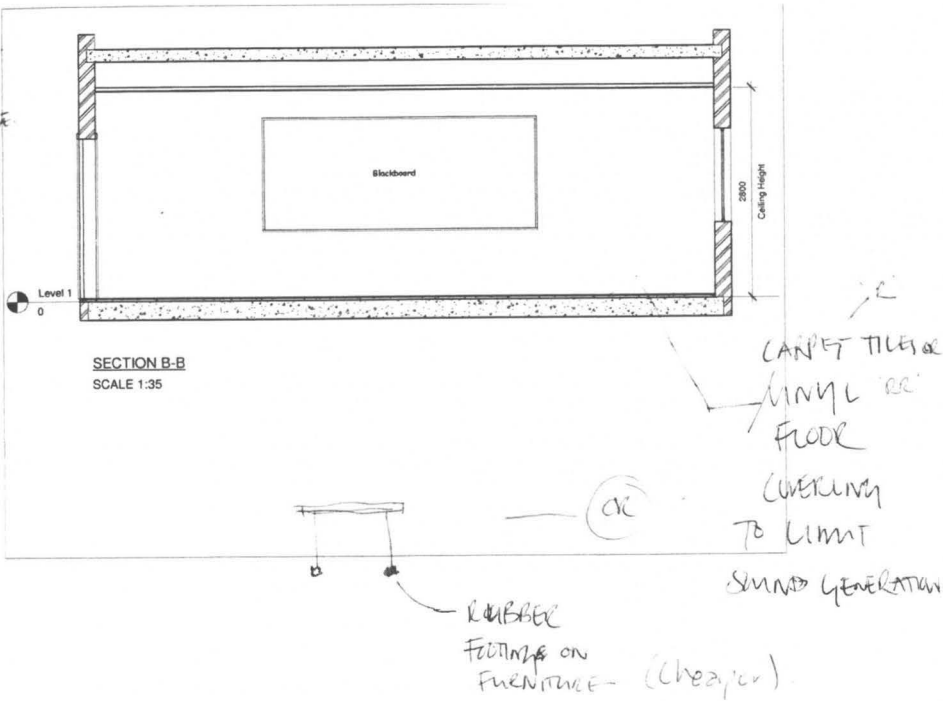


Figure 4.25. Cross-section of the front wall of the classroom.

Participant 10 also discussed implementing carpet tiles on the entire floor to reduce noise when furniture moves or when the occupants are walking (Figure 4.25 and Table 2 (Appendix H) under the dominant theme of ‘Carpets/flooring for reverberation absorption’).

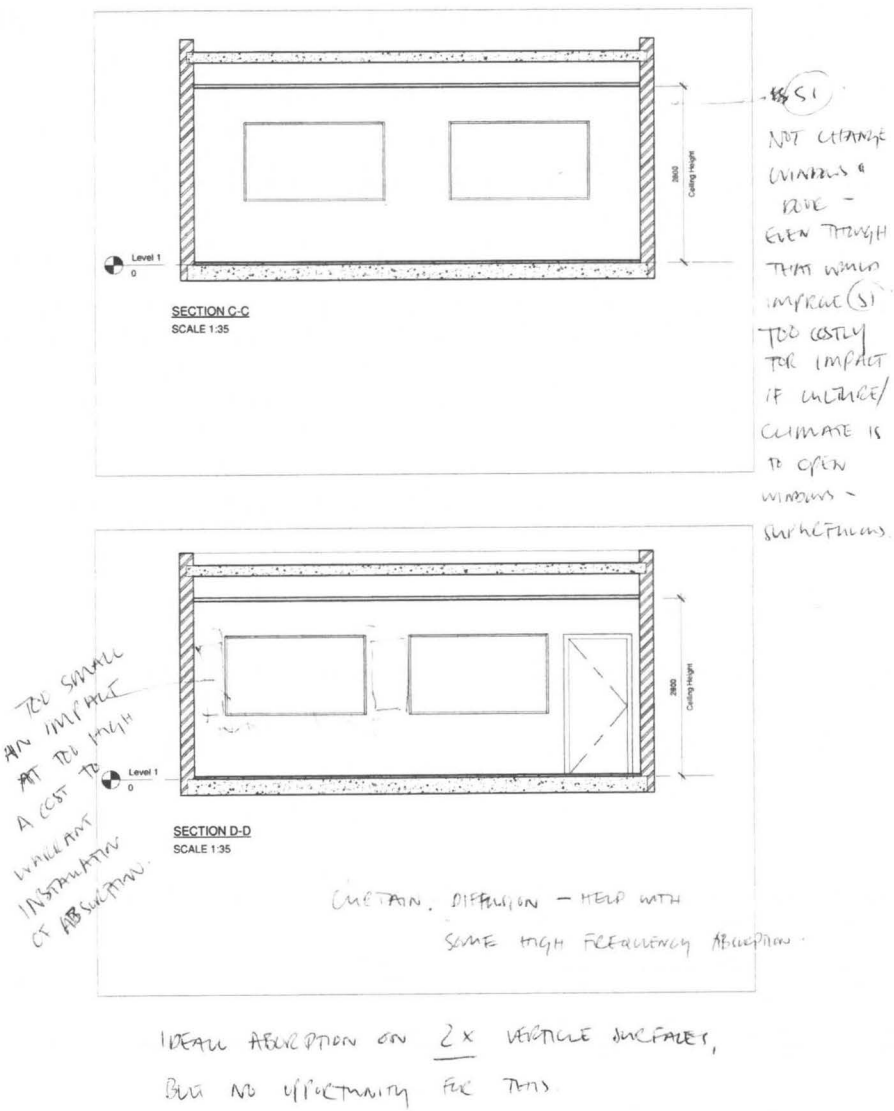


Figure 4.26. Drawings indicating Participant 10's thought process in choosing appropriate acoustic treatment strategies.

Referring to the second drawing of Figure 4.26 and Table 2 (Appendix H) under the dominant theme of 'Curtains' Participant 10 explained that curtains do not necessarily improve the acoustic conditions inside a classroom, but rather creates a diffusion of sound and scatters the sound into the environment. According to the participant, this can make the listening experience more comfortable. The participant mentioned that the cost is not warranted as the area is too small to create an impact.

Referring to the first image in Figure 4.26 and Table 3 (Appendix H) under the dominant theme of ‘Windows and doors’, Participant 10 explained that sound insulation is a very expensive exercise despite the benefits it would have on speech intelligibility.

From the drawings, various suggestions for acoustic treatments were made. The PEI technique elicited responses from the participants that were summarised in the above section. In the following section, the Framework thematic analysis technique was used for the deeper analysis of the participants’ responses.

4.1.2. Framework thematic analysis.

This section continued to address the first secondary objective of the study. The PEI analysis technique was used in addition to Framework thematic analysis as the PEI was not detailed enough to portray the complex thought processes of the participants’ designs and the themes that emerged through the semi-structured interview guide. Framework thematic analysis was used to analyse the data obtained from the semi-structured interview. The analysis generated themes within the interrelated domains of the considerations made by the participants to acoustically treat the existing classroom. Each domain was analysed using Framework thematic analysis. The domains included: treatment to improve reverberation time, treatment to improve ambient noise levels, external treatment, acoustic treatment in the ideal situation, acoustic norms used by the participants, personal experience with acoustics, and speech intelligibility. The drawings were used with the analysis of the semi-structured interviews, this added visual support for the researcher to understand the different considerations made to acoustically treat the example classroom. This allowed the participants’ considerations to ‘come to life’ as this phase of the research is a very visually based task.

Each domain was analysed with examples from the transcribed interviews (Appendix H). The detailed excerpt examples are presented in a table format which can be found in Appendix H. Under the following section, only certain excerpts from the individual interviews were chosen to represent the themes in the table format. There are various sub-themes presented in the table that are related to the more generalised theme sought in the transcriptions.

When the participants were interviewed the researcher felt that there was a common and heightened belief of the importance of having appropriate acoustics in a classroom amongst the participants. A number of the participants were excited to hear that research is being done on the topic of acoustics in the classroom. There were also saddened feelings as the participants realised that limited resources can cause barriers to the learning experience in the classroom.

4.1.2.1. Domain 1: Acoustic treatment to improve reverberation time.

The first domain generated from the data was the *acoustic treatment to improve reverberation time*. The participants discussed their considerations regarding the importance of improving reverberation time in the example classroom. The detailed excerpts from the interviews can be found in Table 2 in Appendix H.

Table 4.1

Acoustic treatment to improve reverberation time.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
Prioritise acoustic treatment for reverberation time.	4	Financial considerations	Participant 4, line 28-29: "But to treat the space and for internal acoustic quality, it's not a huge, relative to the rest it's the least expensive and easiest to do here."
	1	Treatment of reverberation time has a knock-on effect on ambient noise levels	Participant 7, line 134-135: "People shout less, and you'll see that by just dealing with reverberation time it will bring down this ambient noise level significantly."
Acoustic treatment of the ceiling	2	Acoustic ceiling clouds/islands	Participant 2, line 63: "I am going to talk about acoustic islands which is um... when you just suspend a piece of acoustic material."
	3	Positioning of acoustic ceiling	Participant 1, line 181-182 "Okay or where the learners/seating is placed because that is obviously when the children talk the sound actually goes up, bounces from

		clouds/islands	the ceiling...”
	7	100% ceiling cover with acoustic tiling	Participant 7, line 29-30 “...if you did the entire ceiling you'd drop the reverberation by quite a bit.”
	5	Cheapest and most effective way to introduce absorption	Participant 7, line 34-36 “...so when looking at the ceiling it is the cheapest, easiest, and fastest way of doing it um... that's in terms of reverb.” Participant 10, line 42-43 “Remove ceiling and install acoustic lay-in ceiling so that would then be in a grid, which is cheaper.”
Acoustic treatment of the back wall	6	Constructed acoustic panels	Participant 4, line 264 “...get your main contractor or a shop fitting contractor construct wall panels which is um... it's a fairly simple detail.”
	4	Improves reverberation time and echo	Participant 4, line 236-240 “...you certainly can improve the acoustics of the room by introducing something on the back wall which just prevents that you know that extra energy that's coming back to the 'stage' coming back to the learners off the back wall. Um... so in terms of wall treatment that's the only area I would consider.”

			Participant 5, Line 210-210 "...that (<i>acoustic panels on back wall</i>) will also obviously help with the reverb (<i>reverberation time</i>) and increase the speech transmission. Um... but it'll also help with the slap back for the teacher..."
	2	Dual function of wall panels	Participant 6, line 36-39 "...if we can treat that (<i>the back wall</i>) with an acoustic material and there is a couple on the market and I didn't think of what we can use there but even if it's a felt or... and what is nice because it's a dual function is if you use a pin boards with a cork type material it actually absorbs sound..."
Carpets/ Flooring to improve reverberation time	2	Carpets do not provide efficient absorption	Participant 7, line 76 "...carpet isn't going to give you much but it helps a little."
	3	Functional for reading corners or sitting on the floor	Participant 10, line 326-327 "...especially in grades 1-3 where you're getting kids to sit on the floor, it's quite nice because you have a bit of a thermal um... it's not a cold material... use carpet tiles so that you can replace one..."
	2	Carpet tiles	Participant 10, 327 "...use carpet tiles so that you can replace one..."
	4	Loose carpets	Participant 1, line 465-466 "...the carpet doesn't have to go all the way to the back,

			just maybe in the front where ja maybe from the front wall to where the first chairs start.”
Health hazards with using mineral wool as absorption material	3	Mineral wool should not be used in classrooms	Participant 1, line 66 “...The mineral wool, if you looking at classrooms and children and health and safety and all that kind of stuff.” Participant 4, line 289-306 “...glass wool is typically the cheapest... glass wool is obviously it releases fibres so when it's unfinished it can be a problem and it can be dangerous especially in a classroom environment...”
‘Homemade’ acoustic panels for the ceiling and back wall	2	-	Participant 3, line 99-110 “I'm going with home-brew stuff okay... buy batting which is basically like stuffing that you would like make a duvet or quilt out of... I'd staple material to the back – any kind of material. Um... to stick batting to the material and then I'm going to get felt material and I'm going to cover the whole thing with felt which will give you a lot of absorption.”
Curtains	1	Positive effect on improving	Participant 6, Line 42-43 “... the best treatment for acoustics is normal curtain and I know curtains aren't a traditional thing that you put into a classroom...”

		reverberation time	
	3	Limited effect on absorption	Participant 10, Line 217-223 "... so quite often people will say like curtains may help reduce the sound pressure level, it won't actually... it will only reduce certain sounds which are almost masked out by your mid and low-frequency sounds anyway... so it does help with diffusion and it also does create some um... high-frequency absorption... it does help with some perceptual privacy so there's more what a curtain is classically designed for limiting light or so you don't see kids walking past or um..."
Egg crates	1	-	Participant 6, line 77-81 "The best um... sound absorption is actually egg crates... And I mean its cost-effective egg crates on that back would make such a huge difference on your sound and that's a cost-effective way hey. Each pupil can bring one and then you like halfway there."
Shelving and other absorptive	2	Sound diffusion (bookshelves)	Participant 10, line 153-155 "The second thing is to diffuse (<i>sound</i>) so things like bookshelves on the back wall, um... so any kind of furniture that could help break that reflection and create sound diffusion and break it towards the ceiling so that it

furniture			can be absorbed.”
	1	Sound absorption (chair bags and bean bag chairs)	Participant 9, line 43-45 “... getting chair bags, the chair bags will add some softness to that... and maybe have in the corners of the classes some bean bags or just sort of reading corners and um... just to try and absorb some of the sound...”

There were nine dominant themes that emerged from the data that reflected the participants' considerations of acoustic treatments to improve reverberation time. These themes consist of: prioritising acoustic treatment for reverberation time, acoustic ceiling treatment, acoustic wall treatment, carpets/flooring for reverberation absorption, health hazards with using mineral wool as absorption material, 'homemade' acoustic panels for the ceiling and back wall treatment, curtains, egg crates, and shelving and other absorptive furniture. The participants had various common considerations.

Prioritise acoustic treatment for reverberation time: As per Table 4.1, there were a number of participants who mentioned prioritising reverberation treatment rather than sound insulation treatment for ambient noise due to cost versus effectiveness. Participants also mentioned that sound isolation, to treat ambient noise, is mainly dependent on the structure of the classroom, and would be a very pricey fix as it would include replacing windows, doors, and the structure of the example classroom. However, according to the participants, reverberation treatment involves adding certain materials into an existing space in order to absorb sound energy. With this, the participants explained that there are various ways to implement absorption into a space with a wide range of costs. Participant 7 mentioned that by improving the internal acoustic conditions of a classroom it has a knock-on effect on the ambient noise level as the behaviour of the children and teachers should change with an improvement in acoustics. For example, there will be a quieter environment and therefore less shouting due to the improvement in the listening and teaching space.

Acoustic ceiling treatment: The participants mentioned two options of acoustically treating the ceiling; namely, ceiling 'clouds' or 'islands' or installing a drop-in ceiling containing absorptive acoustic ceiling tiles. Two out of the ten participants opted for acoustic 'islands' and seven of the ten participants opted to treat the entire ceiling. Only one participant, Participant 9, did not opt for acoustic treatment on the ceiling.

Two out of ten participants that chose to use acoustic ‘islands’ explained that it would be cheaper to home-make the acoustic ceiling panels and install them onto the existing ceiling. However, seven out of ten participants who chose to cover the ceiling with absorptive acoustic tiling explained that it would be cheaper to install acoustic ceiling tiles, even at a Class C level with an NRC rating of 0.7. Participant 1 mentioned that the more absorption you bring into a space the lower the reverberation time will be. This is where low-cost and effectiveness shows high relevance. The participants illustrated that instead of adding many materials into a classroom, one can start with the ceiling and improve the reverberation time dramatically. This can be seen further on in the quantitative results chapter which will be further analysed together with the qualitative data in the discussion chapter.

Acoustic wall treatment: Nine out of ten participants opted for having absorptive wall panels on the back wall. The reasoning for choosing the back wall over the side or front wall differed; namely, to introduce more absorption into the classroom, to improve the slap-back echo, and due to there being no space on the side walls or front wall due to the windows and blackboard. The only participant that did not opt for acoustic treatment on the back wall was Participant 2. The participant wanted to keep acoustic treatment as cheap as possible. Participant 9 used acoustic wall treatment as her predominant choice of acoustic treatment by implementing the use of a dado rail. According to Participant 9, a dado rail is a term used to describe acoustic wall panels that extend to one meter high from the ground up. A few participants also mentioned that functionality within a classroom is important, and so they would double up the acoustic wall panel as a pinboard too. This allows the teacher to place relevant pictures up. However, Participant 5 mentioned that the teacher should be encouraged not to cover the panels with pictures as it defeats the purpose of the absorption of the panel. The acoustic panel needs to be free of any materials that may disrupt the sound energy from

penetrating into the acoustic panel to be absorbed and thereafter improve the reverberation time.

Carpets/flooring for reverberation absorption: Carpets or a change in flooring were opted for by six out of ten of the participants and four out of ten of the participants did not consider changing the flooring. Carpets were chosen over vinyl flooring as, according to the participants, they are cheaper to install. Loose carpets were opted for by four out of the ten participants and carpet tiles to cover the whole floor were opted for by two out of the ten participants. Loose carpets were chosen by the participants due to maintenance issues, it would be easier to clean and replace as they are removable. Five out of six participants considered introducing carpets for the purpose of increasing the surface area of absorption into the classroom. However, Participant 10 made an interesting statement regarding the need for appropriate flooring in a classroom space. Participant 10 expressed that the carpet may not have that much of a significant impact on the reverberation time or ambient noise levels, but it will reduce the noise of furniture moving or people walking.

Health hazards with using mineral wool as absorption material: The participants mentioned two different materials to be used as absorption material in the acoustic 'islands' or the wall panels; namely, polyester and mineral wool fibreglass. Only three out of the ten participants mentioned the health hazards that are associated with the use of mineral wool as an absorptive material, especially in a classroom setting. These three participants mentioned that the mineral wool tends to float around in the space and can be inhaled by the occupants within the space which is a major health hazard. The three participants emphasised that even though the mineral wool may be cheaper than polyester, it is not a safe option for the classroom and should be avoided.

'Homemade' acoustic panels for the ceiling and back wall treatment: The emphasis of low-cost yet effective considerations to acoustically treat a classroom was taken into account by a number of the participants. Two of the ten participants mentioned that they would go for a home-made option of creating absorptive acoustic ceiling panels or wall panels by working hand-in-hand with a building contractor or a basic carpenter. The participants emphasised that by combining a number of materials with a very simple structure, anyone could implement this design into creating their own acoustic panels for either the ceiling or the wall.

Curtains: Curtains were considered to increase softness into the classroom to act as a surface area for absorption by five out of the ten participants. The participants who considered the curtains for the example classroom acknowledged that the acoustic benefits of the curtains were limited, yet adding any sort of soft material in the example classroom would assist with absorbing and redirecting sound towards the acoustically treated roof for absorption. Participant 7, a participant who has done projects in the classroom setting explained an interesting concept. Through experience in treating a classroom, the participant explained that using the curtains themselves are not necessarily what creates an improvement in the reverberation time, but rather the space between the window and the curtain. The participants affirmed that the gap between the window and the curtain is important as this is where a lot of the sound energy is dispersed and thereafter absorbed, and therefore less sound energy is being released into the classroom area where teaching is taking place.

Egg crates: Only one participant mentioned this method of using egg crates to reduce the reverberation time in the example classroom. Participant 6 mentioned that the egg crates should be placed on the back wall for sound absorption.

Shelving and other absorptive furniture: A number of the participants considered using furniture made of natural materials, such as wood, to be used as sound absorption materials in the example classroom. As mentioned by Participant 10 (Appendix H), the furniture will diffuse the sound energy by breaking the sound reflection and redirecting it to the acoustically treated ceiling for absorption. The participant further explained that this allows the ceiling to be used at its maximum capacity as sound from different directions will be redirected towards the ceiling to be absorbed instead of absorbing sound that interacts with the ceiling incidentally.

4.1.2.2. Domain 2: Acoustic treatment suggestions to improve the ambient noise level.

The second domain is *acoustic treatment suggestions to improve the ambient noise level*. The participants discussed their considerations of the acoustic treatments which they would use in order to improve the ambient noise level in the classroom. Table 4.2 contains examples of the excerpts from the interviews that reflect these considerations, detailed excerpts can be found in Appendix H.

Table 4.2

Acoustic treatment suggestions to improve the ambient noise level.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
Financial limitations for sound insulation	6	Structural changes are too expensive to consider	Participant 1, line 331-334 “Um... ja low cost that is a bit of a tricky thing...the way to increase your soundproofing would be to add mass or weight to the surfaces or to the boundaries...”
Windows and doors	1	Double glazing on the windows	Participant 1, line 335-337 “...because you've got a glass that would be your mostly your weakest link between the outside and the inside. So one way of improving the soundproofing would be to add a second layer of glass um...” Line 405-407 “...adding thickness to the glass and you're adding some air space between the two glass panels so that improves the soundproofing as well.”
	3	Rubber seals for the	Participant 5, line 91 “...we can put seals on these openable windows which would

		windows	help to an extent...”
	4	Rubber seals for the door	Participant 1, line 344 “...depending on the space or how much space you've got between the door and the frame you could add some rubber seals.”
Shutters/ Curtains	2	Curtains to assist with noise reduction	Participant 6, line 109-111 “... your curtains on your windows or blinds will actually help reduce your sound coming in from the outside as well.”
	1	Shutters to assist with noise reduction	Participant 3, line 201 “Solid shutters that can be closed only when there is PE going on outside.”
Replacing the fans	1	Considerations for temperature control in the classroom	Participant 4, line 409 “...in summer another huge aspect of teaching is temperature, it can't be blazing hot or learners fall asleep.”
	2	Ventilation considerations	Participant 10, line 278-282 “...if you don't have fans you don't have any fresh air supply which means you actually cannot close the windows because now you have a carbon dioxide increase so you might be improving the disruption level, but now your kids are getting less oxygen.”

Behavioural and school management	6	Timetable management to reduce noise during class time	Participant 8, line 207-209 "...the school also needs to manage their timetable so that there isn't a lot of traffic while there's classes going on... I'm not too sure how to manage that..." Participant 10, line 269-271 "I'd rather look at cultural things so like how is your scheduling done, how is the timetable worked out, so that almost that disruption is controlled in terms of the activity so..."
Improving ambient noise levels to increase speech intelligibility	2	-	Participant 4, line 499-501 "Um... I think if we can bring the ambient noise levels down and get the teachers to speak at a reasonable level, we can – we might not eliminate noise between classrooms, but it might be to the point that it is manageable."
Rearrangement of the classroom to manage the	1	-	Participant 9, line 32-37 "... you have noise from the corridor here and then you've got noise from the sports field over here... on the left-hand side, so I would actually turn the chairs around so that your view is actually towards the corridor even though you... because at the moment you... you're hearing from this side and

effects of ambient noise levels			this side... whereas if you turn it around you'll sort of have your back against the sports field and look towards this space.”
Flooring to improve ambient noise levels	1	Reduce the generation of noise with correct flooring	Participant 10, line 307-312 “...metal on a hard floor usually generates a lot of noise so either rubber footing furniture so that by moving desks and so on you're creating less noise that you're having to absorb somehow. Or by changing the floor surface and there it would it would need to be something a floor, often people think that an acoustic floor is going to absorb sound it's not a floor to absorb sound it's a floor to make sure that sound is not generated.”

There were nine dominant themes that emerged from the data that reflected the participants' considerations of acoustic treatment to improve the ambient noise level. These themes consist of: too expensive to conduct sound insulation, treating windows and door, shutters or curtains, replacing the fans, behavioural and school management, improving ambient noise levels to increase speech intelligibility, rearrangement of the classroom, treating reverberation assists with absorbing sound pressure levels, and flooring. The participants had various considerations that overlapped.

Too expensive to conduct sound insulation: Many of the participants mentioned that it would be a very costly exercise to make changes in order to improve the ambient noise level as this would be the need for sound insulation. According to the participants, sound insulation involves changes in the structure of the example classroom which is very expensive. The participants explained the difficulty in sound insulation in the themes that follow.

Treating the windows and the door: According to the participants, sound insulation is a complex exercise to implement into an already existing structure. It requires soundproofing all possible openings in the structure to ensure that sound cannot enter when these openings are closed. The participants spoke about the concerns of the windows and the door, as they present as two of the weakest links in relation to preventing noise from entering the classroom. Flanking of noise, noise that enters through the windows or door from other classrooms is highly common in classrooms. Therefore the participants suggested that rubber seals should be placed on the edge of the windows and door to ensure a solid seal is formed between the frame of the window and the frame on the wall. Some of the participants emphasised that the seals should be as tight as possible to ensure that when these openings are closed they create a soundproof barrier to improve the ambient noise internally. The participants believe that in this scenario it would be the cheapest option to implement some

degree of sound insulation. According to the participants, replacing doors and windows with a higher spec for sound insulation is not an option for low-cost considerations.

Shutters or curtains: Curtains were not only considered for the improvement of reverberation time (as mentioned in Table 4.1) but for the improvement of ambient noise levels too. Participants mentioned that they would use the curtains to absorb the excess sound energy in the example classroom. Participant 3 mentioned the creation of wooden shutters that could act as a barrier for the window for when physical education is occurring outside the classroom.

Replacing the fans: Two of the participants strongly considered the replacement of the old racketing fans. According to Participant 10, noise generated by the fan can cause a lot of distraction and can be very difficult for the learner to tune out in order to hear the teacher. Participant 4 mentioned that it is not only noise that causes a barrier to learning but other conditions within the classroom too, such as, temperature. Participant 4 mentioned that it is imperative to have air-flow within the classroom and the windows are not ideal for this purpose as it creates greater vulnerability to external noise inside the classroom.

Behavioural and school management: A number of participants mentioned that behavioural and school management would be a cost-effective strategy to improve the ambient noise levels. Changing timetables, schedules, and how the classrooms run was suggested by six out of the ten participants. This included ensuring that sports or the use of the recreational area were used during non-learning times and that all classrooms had breaks at the same time to avoid interruptions. Participants expressed that from a cost-effective perspective this is a low-cost option to improve the ambient noise from a management point of view.

Improving ambient noise levels to increase speech intelligibility: Two participants mentioned that the higher the ambient noise level is the less speech intelligibility will be. The participants expressed that by improving ambient noise levels it has a knock-on effect of how the teachers teach. The participants who suggested this mentioned that the teachers will not have to raise their voices, and it could have an effect on the learners' abilities to understand what the teacher is saying without the highly competitive signal-to-noise levels.

Rearrangement of the classroom: Participant 9 considered rearranging the seating layout in the classroom by placing the learners' backs towards the sports field and them facing the recreational area. This could introduce visual distraction, but the participant mentioned that a blackboard could be placed in front of the windows, even though it is not an ideal space.

Flooring: Participants mentioned that the sound of metal furniture on the floor generates a lot of noise. Participant 10 considered placing rubber footing on the legs of the chairs and tables to prevent noise generated from the metal dragging on the floor, or, the floor could be changed. Participant 10 shared an interesting fact about acoustic flooring, it is not necessarily about sound absorption but rather ensuring that sound is not generated by furniture moving on the floor.

4.1.2.3. Domain 3: External treatment suggestions to improve internal acoustics.

The third domain refers to *external treatment suggestions to improve internal acoustics*. The examples of excerpts from the interviews, found in Table 4.3 below, reflect the participants' considerations to improve internal acoustics by treating the outside of the classroom. Detailed excerpts from the interviews can be found in Appendix H. These considerations were based on whether there was an extended budget, as well as, long term solutions.

Table 4.3

External treatment suggestions to improve internal acoustics.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
Barrier around the school by the main road	3	Plant trees	Participant 9, line 171-173 "...some sort of landscaping buffer here with quite tall trees um... and the same kind of thing on this side, just so that they that gets absorbed a little bit... um... but more than that you can't really do..."
	1	Brick wall	Participant 7, line 158-161 "...making something like a brick wall on the boundary instead of an open fence... um... this is the site plan... put a brick wall on the boundary..."
Barrier outside the classroom by the sports field	1	Hedge	Participant 6, line 99-102 "... but if you can put a barrier like a hedge growing there then it would make a huge difference. Just like it's the same thing with the sound here where um... basically gets absorbed by the hedge and even here with the sports field either trees or hedges along there."

	1	Brick wall	Participant 7, line 162 "...and certainly look at putting some sort of barrier almost the whole way on the sports field... Brick can do..."
	2	Trees	Participant 8, Line 113-114 "...a lot of landscape architects tend to plant trees in areas in between somewhere where they want to reduce the noise and the highway for instance..."
	1	Berm	Participant 8, line 116 "Um... something like a berm which is soil mass is much more effective (<i>than trees as a barrier</i>)."
External acoustic treatment	1	-	Participant 3, line 170-176 "...options for outdoors... hm... so you could add an acoustic ceiling it would be costly um... but probably the best option you've got or even to add panels similar to the ones we made for the back wall. Yes, let's do that go budget. Add absorption panels to soffit (underside of corridor slab above). Um... similar to homemade wall panels. So that's going to help the noise that enters this corridor not to bounce around and enter the classrooms. So it actually won't bounce and it will be captured. So it will reduce the noise in the classroom."

Custom made absorption panel on the outside of the windows	1	-	Participant 1, line 433-439 "...if the window opens like this okay, if you put like like a type of build like an out of metal and preferably like perforated metal like you've got a metal plate with holes in so you've got like a box, and you put the absorption material inside and you cover it with perforated metal and then the sound that actually um... comes through the window and the bottom will be absorbed by this box. And then less sound will actually go come in the window."
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Four dominant themes were found within domain three; namely, barrier around the school by the road, barrier outside the classroom by the sports field, external acoustic treatment, and custom made absorption panels outside the window.

Barrier around the school by the road: The participants mentioned that the best way to treat ambient noise levels is to treat the source of the problem. Unfortunately, the road noise is very difficult to treat and therefore four out of the ten participants considered building a barrier around the school to reduce the noise from the road impacting the example classrooms learning environment. Trees were considered by three out of the ten participants and a brick wall by one of the participants, these were considered to be long-term solutions.

Barrier outside the classroom by the sports field: The participants mentioned that they would consider placing a barrier outside the classroom on the side of the sports field to reduce the noise entering the classroom. The participants considered barriers such as hedges, trees, a soil berm, and a timber or brick wall.

External acoustic treatment: One of the participants considered placing homemade acoustic panels on the soffit of the corridor to absorb more sound that may enter the classroom.

Custom made absorption panel outside the windows: Participant 1 created a sound absorption box that would fit on the bottom of the window on the external side of the example classroom. The participant explained that less sound will enter through the window as a lot of it would get absorbed by the absorptive material inside the perforated box.

4.1.2.4. Domain 4: Acoustic treatment suggestions in the ideal situation.

The fourth domain refers to *acoustic treatment suggestions in the ideal situation*. The examples of excerpts from the interviews, found in Table 4.4 below, reflect the participants' considerations with acoustic treatments in ideal situations, meaning, the acoustic treatments they would implement if there were no budget limitations. Detailed excerpts of the interviews can be found in Appendix H.

Table 4.4

Acoustic treatment suggestions in the ideal situation.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
Mechanical ventilation	5	Improves ambient noise levels	Participant 5, line 319-323 “So... I think I think if the reverb situation is sorted you've done really well... from an ambient noise level perspective, it's always an issue. I think it's always going to be an issue unless you start air-conditioning the rooms and start keeping everything closed...”
Exchanging windows and doors	3	Sealed and non-openable windows	Participant 1, line 480- “...we talking budget obviously there are more things that you can do to a classroom or to a room but um... for example, adding like a drywalling... silicone the (<i>window</i>) frames closed and that already made a big difference, but obviously now if you silicone them you can't open them anymore.” Participant 4, line 460-462 “Um... so, if we had mechanical ventilation, we could

			put uh... you know... we could replace the windows with non-openable window sections, um... you'd still be able to get a comfortable environment and we'd immediately improve our sound insulation with the existing...”
	3	Reinstalling the windows	Participant 2, line 527-530 “...like you're already encouraging visual distraction I would actually say, block a portion of the window and allow a portion to let the light come through. If you can actually have the top portion to be openable and the lower level actually just block out.”
	3	Double glazing on the windows	Participant 8, Line 90-97 “But the difficult areas is your windows. And you get a similar thing for windows, where all our traditional windows are one single glass pane like these but with a green star ratings, the new laws with a new build or a refurbishment you have to place it with at least a certain specification level and most of the things turn out to be very expensive glass or what is called double glazing which is a frame with two pieces of glass. And that is quite effective as well, and that also has an acoustic rating to a certain degree.”
	2	Replacing the doors	Participant 4, line, 514-515 “Um... replacing doors, you know even a solid core

		with solid core doors	door, you know a new solid core door with seals you're looking at R7000-R8000 per door.”
Higher rating ceiling designs	1	Class A ceiling tiles	Participant 4, line 163-164, “...the advantage of using a Class A ceiling is that per square meter we looking at about a 20% more efficient ceiling.”
Wall barriers	1	Outside classroom	Participant 3, line 191-192 “...one could try and add a wall let's say about one and a half meters away from the window but it would have to be at least 3 meters high, which is high, it's higher than the classroom. Um... and that becomes expensive and difficult and it's going to help the upstairs classroom...”
	3	Outside barrier of school	Participant 5, line 314-317 “Anything more is going to be a big cost, it depends on how much noise pollution you are experiencing from the main road. You do get noise barriers that can be installed but once again who's going to pay for that? The school isn't going to do that.”
Flooring	3	Vinyl flooring	Participant 6, line 122-123 “Recently in a school we actually put a vinyl in that actually has an um... like a soft layer underneath it so that helps a bit because it's not just your concrete with a vinyl um... on top. But it starts to become very

			expensive.”
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Five dominant themes were derived from domain four; namely, mechanical ventilation, exchanging windows and doors, complex ceiling designs, wall barriers, and flooring. These five themes reflect the participants' desired considerations if there were no budget limitations. This enabled the researcher to understand how the participants were thinking to get to the low-cost yet effective consideration to acoustically treat the example classroom.

Mechanical ventilation: Five out of the ten participants considered mechanical ventilation to be an ideal priority in a classroom. The participants affirmed that mechanical ventilation allows for sound insulation as the windows and door in a classroom can be closed to prevent vulnerability to external noise sources as well as ensure a supply of air flow. The participants mentioned that mechanical ventilation has its own issues with noise, however, an attenuator can be used to ensure that the noise generated is kept to a minimum.

Exchanging windows and doors: As the participants mentioned previously, the windows and door in a classroom are the weakest link to increased vulnerability to external sources of noise. Seven of the ten participants mentioned that sealing the windows and doors is imperative to sound insulation. The seven participants expressed that exchanging the windows to double glazed windows or to windows of a higher spec for insulating the classroom from noise was recommended. However, the participants also mentioned that this is very costly, which is why this is considered to be an 'ideal' plan should there be an absence of financial or resource limitations.

Complex ceiling designs: Many of the participants chose to use Class C acoustic ceiling tiles instead of Class A acoustic ceiling tiles due to the pricing differences. As seen with the participants' choices of materials, Class C acoustic tiles usually have a noise reduction coefficient (NRC) of 0.7 whereas Class A acoustic ceiling tiles usually have an

NRC of 0.8. Participant 4 mentioned that the Class A acoustic ceiling tile has around 20% more efficiency at absorbing sound reflections, in other words, more efficiency at improving reverberation times. Ideally, Class A acoustic ceiling tiles could be used, but due to this study focussing on low-cost considerations to acoustically treat an example classroom, eight out of ten of the participants opted for a Class C acoustic ceiling tile.

Wall barriers: As seen in Table 4.4, three participants considered a long-term solution to building a barrier around the school's perimeter in order to prevent noise from the traffic interrupting the learners in the example classroom. Another participant considered building a wall barrier on the sports field side to prevent noise from the sports field entering the example classroom during learning time. All three of the participants who considered this wall barrier expressed that this was not a feasible plan, but rather in the ideal world it would bring down the ambient noise levels in the example classroom.

Flooring: Two of the participants mentioned using carpets as flooring for the example classroom to assist with absorbing excess reverberation as well as limiting noise generated by furniture movement. This was a low-cost consideration that has limitations of its own, as the participants mentioned, maintenance of carpets can be an issue. Therefore, two of the participants mentioned the use of vinyl flooring as an acoustic floor. According to the participants, vinyl flooring is easier to maintain than carpets however, is a lot more expensive.

4.1.2.5. Domain five: Acoustic norms.

The fifth domain refers to the *acoustic norms* that the participants referred to or used for their considerations to acoustically treat the example classroom. The example excerpts from the interviews are found in Table 4.5 on the following page, it shows the variety of norms or absents thereof that the participants referred to. Detailed excerpts of the interviews can be found in Appendix H.

Table 4.5

Acoustic norms.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
Reference unknown by the participant	3	The participant could not provide a reference for acoustic norms	Participant 6, line 149-153 “No not on acoustics (<i>norms unknown</i>), a classroom is the only norm we use is the size, and that gets depicted by um... the client that we actually we use and um... we do government schools and private schools um... look here the last... the... in government they've actually said you know what this is the standard classroom this is the size of a standard classroom and even this is the finishes as well hey...”
South African acoustic norms	3	Participant mentioned that there are no acoustic norms in South Africa	Participant 2, line 70-71 “...within this country, we don't really have um... standards for reverberation time we have standards for ambient noise levels.”

	2	SANS 10130 for ambient noise levels	Participant 4, line 31 “I would use the SANS 10103 where the maximum noise level for a classroom is 40dB.”
International acoustic norms	2	Australian and New Zealand acoustic standards	Participant 2, line 83 “Okay, national standards for reverberation times don't quite exist (<i>in South Africa</i>) um... so only we refer to actually Australian (<i>reverberation time</i>) standards.” Participant 5, line 249-252 “... I don't know if you've seen the standard where they talk about reverb time actually a New Zealand standard that we use in South Africa because we don't have a SANS standard for reverb...”
	1	British acoustic standards	Participant 2, line 98-99 “So, education spaces we are trying to get to a maximum of 0.8, but this is already actually this is based on British standard ISO1.1.14.”
	1	Global acoustic standards	Participant 10, line 248-250 “... norms globally for reverb time is 0.4 or 0.5 seconds so that's a whole 1 second more which means even if you were to...”

Three main themes arose from this domain of acoustic norms. The participants mentioned that references were unknown, South African acoustic norms, and international acoustic norms.

Reference unknown by participant: Three of the participants mentioned norms but did not know where their reference originated from. These three participants applied norms that they felt were appropriate for a school environment. These norms were not research-based and did not originate from regulations or documentation.

South African acoustic norms: Three of the participants mentioned that South Africa does not have a norm for reverberation time. None of the participants were able to provide a reverberation time norm from South African documentation or regulations.

International acoustic norms: Two of the participants were using acoustic norms originated from New Zealand. And one participant referred to their acoustic norms as ‘globally’. Participant 5 believed that the norm for reverberation time fell between 1 and 1.2 seconds, he then used his phone to research an acoustic norm specifically for primary schools and found that the norm was actually between 0.4 seconds and 0.5 seconds. The participant was surprised to see how far off the original norm was from the norm that he researched.

4.1.2.6. Domain 6: Personal experience.

The sixth domain refers to the *personal experience* of the participant in relation to acoustics in classrooms and in general. The example excerpts from the interviews can be found in Table 4.6 below. Appendix H contains detailed excerpts.

Table 4.6

Personal experience.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
Ceiling treatment	2		Participant 1, line 29-31 "...from my experience the most um... effective surface or boundary to add some absorption material would be the ceiling"
Clients' willingness to pay for acoustic treatments	1	-	Participant 9, line 142-145 "...clients are very reluctant to spend a lot of money on these things so we try to get as much bang for your buck so we try to put in the carpets, and try to choose material so that there are some absorptive qualities to it... I mean even acoustic ceilings um... it's not done it's just too expensive..."
Legacy architecture	1	Designing for the eyes and not function	Participant 2, line 262-264 "And you know you see all these buildings in Sandton where they are fancy, big buildings. This is what you call, it is just legacy architecture. Architects approach buildings from outside without thinking of how

			people are going to do inside.”
Speech intelligibility	1	Poor STI causes poor listening experience	Participant 2, line 448-451 “Ja you see now you have to take that into the equation. But then you go back to STI of 0.3 and 0.4 and with this scenario is like, you're only hearing 30% of what is being said by the teacher. Many people don't see that when I point this out, then say my G-d they can only understand 30% no wonder they become mischievous.”
Acoustic treatment	1	Two phases of acoustic treatment	Participant 4, line 71-73 “So I think maybe for this classroom I'll do it in in sort of two phases if you will. There's treatment of the space or speech transmission in terms of internal acoustic quality and then I'll look at possible options of improving the sound insulation of the shell.”
	1	Covering back wall acoustic panels with posters impacts effectiveness of absorption	Participant 5, line 220-226 “And what I've seen in a lot of classrooms is that uh the teachers actually cover up these back walls with posters, and stuff because they always want to showcase something to make the class more relevant I suppose um... because I have seen some classrooms with this kind of band (<i>acoustic panels on back wall</i>) but it being covered up in posters which then... Defeats the purpose

			of this band.”
	1	Acoustics is only addressed following construction if a problem is reported	Participant 6, line 144-147 “But I think with acoustics is one of the actually the most important thing that needs to be addressed in the classroom and I think where you going is quite awesome if there can be minimum standards that everyone has to adhere to it would actually help um... I mean our kids as well...”
	1	Carpets and curtains	Participant 7, line 18-21 “So one of the things that I didn't think would make a huge difference did make a big difference was curtains. So low cost it's not ideal it's not perfect but it does make a bit of a difference. They were getting I think 1.2 seconds reverb time and we got it down with carpet and curtains we got it down to 0.6 seconds.”
	1	Three areas to focus on: absorption, diffusion, and reducing sound generation	Participant 10, line 330-332 “One... add absorption two... create diffusion and three would be limit sound generation so like adding a carpet, or vinyl floor, or rubber feet. And then additional things like replace the fan and so on...”

The sixth domain contained five dominant themes which emerged from the data; namely, ceiling treatment, clients' willingness to pay for acoustic treatment, legacy architecture, speech intelligibility, and acoustic treatment.

Ceiling treatment: Two of the participants mentioned that their choice of prioritising the acoustic treatment of the ceiling came from personal experience of treating spaces. The two participants found that by acoustically treating the ceiling the reverberation time improved dramatically.

Clients' willingness to pay for acoustic treatment: One of the participants mentioned that there is often a lack of willingness from clients to place money aside for acoustic treatment. The participant expressed that clients are not willing to have the extra expense for acoustics as they believe it is not important for the functionality of the space.

Legacy architecture: Participant 2 was passionate about the concept of 'legacy architecture'. The participant referred to this as architects who build for aesthetics and not necessarily for the functionality of the building. This participant found that many buildings have significant issues with acoustics due to acoustics not being considered in the building plan of a construction project. Participant 2 mentioned an important factor, acoustic ceiling treatment is cheaper than buying a new computer or projector for a classroom. The participant believed that it is worthwhile investing in, despite new technology, teaching methods, and other considerations in a classroom, these may not be effective if the learning environment is not conducive for learning.

Speech intelligibility: Participant 2 explained how behaviour is closely related to poor acoustic conditions in a classroom. The participant explained that poor acoustic conditions in a classroom with a speech transmission index of 0.3 the learners are only hearing 30% of what the teacher is saying. The participant linked this to the mischievous behaviour by

learners that are typically seated in the back of the classroom. The participant continued to explain that the learners may be behaving poorly or may be distracted because they are only hearing 30% and therefore may get bored. This participant showed through the experience of being involved in acoustics that behaviour is linked to acoustic conditions in a classroom.

Acoustic treatment: Various participants had very different experiences with acoustic treatments. A participant mentioned that their priority is acoustically treating a classroom internally to ensure that the speech transmission index has improved. Another participant mentioned that acoustic panels were misused by teachers as they would cover them up with posters which would prevent the sound energy from penetrating the acoustic panel to be absorbed by the absorbent material in the acoustic panel. Participant 6 mentioned that acoustics is usually never considered as the professional position lies in the planning and construction of the classroom. The participant explained that acoustics usually only comes up as a topic if a classroom is being refurbished due to acoustic issues, and the interaction with teachers occurs to pinpoint exactly where the issue lies. Participant 7 had specific experience in the acoustic treatment of classrooms. This participant shared a positive experience with the use of curtains in a classroom, which is not usually traditionally used in this kind of space (as mentioned in Table 4.1). Participant 10 mentioned that focus should be placed on absorption as well as diffusion to ensure that the absorption materials added into a classroom are used to their full potential. For example, using wooden furniture to diffuse sound energy towards the acoustic ceiling to be absorbed, in turn improved the overall acoustic conditions of the classroom.

4.1.2.7. Domain 7: *Speech intelligibility*.

The seventh domain refers to *speech intelligibility* and how it is affected by poor acoustics in the example classroom. The example excerpts from the interviews concerning speech intelligibility are included in Table 4.7. Detailed excerpts from the interviews can be found in Appendix H.

Table 4.7

Speech intelligibility.

Dominant Themes:	Number of Participants:	Subthemes:	Excerpts from the Interviews as Examples:
The effects of poor acoustics on speech intelligibility	5	Reverberation time	Participant 1, line 284-289 “the reverb reaches the learners' ears after the direct sound and you basically have like repetitions of the same sound reaching the learners' ears over a matter of um... 1-2 seconds alright. And because of that your reverb actually destroys the intelligibility of what the teacher is saying alright.”
	3	Ambient noise level	Participant 4, line 193-197 “...there are all these other factors, temperature, um... background noise, all of this stuff, but from an acoustics perspective um... if we get that STI right and we get the ambient noise level right and that's setting the foundation for a good teaching environment because you know to be frank, and maybe I am biased because this is what I do and what I love, but it really is the fundamental of education is communication.”

The effects of poor speech intelligibility on behaviour and listening experience	2	Behavioural component	Participant 2, line 162-164 “And if you're sitting here (<i>the back of the classroom</i>) and you're only hearing 30% or only understanding 30% of what's been spoken in front you can get bored so quickly that's why you start becoming naughty and doing your own thing.”
	3	Listening experience	Participant 4, line 166-174 “Ideally more than 0.8 STI... 0.7 (<i>STI</i>) would be good as a rating, and 0.8 (<i>STI</i>) and above is excellent. I wouldn't have anything less than 0.7 (<i>STI</i>), in practical terms that means that about 70% of what is being said is actually being heard and your brain is filling in the rest... anything that is less than 0.7 (<i>STI</i>) and I think um... you know maybe, getting a little philosophical here, you know you start working too hard on filling in the gaps and you losing focus on what's actually being taught.”

Two dominant themes were found in domain seven, namely, the effects of poor acoustics on speech intelligibility, and the effects of poor speech intelligibility on behaviour and listening experience.

The effects of poor acoustics on speech intelligibility: A number of the participants expressed their opinions about the effects of poor acoustics on speech intelligibility. The reverberation in a classroom destroys the intelligibility of what the teacher is saying. Poor acoustics can cause learners to hear only 30% of what the teacher is saying, and the rest they have to try to figure out. By having appropriate acoustics the speech intelligibility index improves, meaning that intelligibility of the teacher's voice improves which creates a good and supportive teaching and learning environment. Participant 4 expressed that the fundamental part of education is communication, in a classroom communication is optimised with good acoustics.

Effects of poor speech intelligibility on behaviour and listening experience: Four of the ten participants expressed that when there are poor acoustic conditions in a classroom it causes poor speech intelligibility, this creates a barrier between the teacher and the learners receiving the teacher's lesson. Participants expressed that learners who are only receiving a small portion of the teacher's voice tend to begin to behave inappropriately. Four of the participants mentioned that the learners get tired, distracted, and misbehave because they cannot overcome the poor acoustics conditions in the classroom.

4.2. Phase Three of Data Collection and Analysis

4.2.1. Quantitative: Converting the data from phase two into numerical data to be analysed in the Sabine reverberation equation.

The conversion of data from phase two was conducted in order to determine the change in reverberation time according to the different considerations provided by the participants in phase two.

4.2.1.1. Changes in reverberation time (seconds) following the simulated implementation of low-cost considerations in acoustic treatments using the Sabine formula.

This section addressed the second secondary objective of the study. The researcher focussed on the change in reverberation time instead of focussing on reverberation and ambient noise levels. Through the process of the semi-structured interview guide with the live drawings, many of the participants mentioned that ambient noise levels can only be improved by either changing the structure of the classroom or treating the source of the noise. Due to this study focussing on low-cost yet effective ways to acoustically treat the example classroom, all ten of the participants focussed on treating reverberation times instead of ambient noise levels. Because of this, the researcher chose to analyse the changes in reverberation as all the participants focussed on the internal acoustics of the classroom.

A table was formed by the researcher to display the various materials that were chosen or the methods of acoustic treatments in the classroom that were considered. Each of these considerations were sized by the participants providing specific measurements. As part of the Sabine formula, each material considered needs a surface area and noise reduction coefficient (NRC). This was calculated by the researcher and included in the table as seen below (Table 4.8).

Table 4.8

Participants' choices of materials, surface area, and the noise reduction coefficient.

Participant	Material	Surface Area	Noise reduction coefficient
One	Six absorption panels from the ceiling made of high-density polyester	One absorption panel is 1200 x 600mm. Total m ² = 4.32	0.7
	Back wall absorption panel made of high-density polyester	One panel is 1200 x 8220mm Total m ² = 9.86	0.7
	Plexiglass on the windows as a cheaper alternative to double glazing (four windows)	1500 x 1000mm Total m ² = 1.5	0.23
	Carpets	2000 x 3000mm Total m ² = 6	0.4
Two	Acoustic ceiling	8220 x 7060	0.7 (Class C)

	tiles (100% ceiling coverage)	Total m ² = 58.033	
Three	Three acoustic islands (ecophon)	1200 x 3000mm Total m ² = 10.8	0.7
	Two acoustic panels on back wall (polyester)	1200 x 3000mm Total m ² = 7.2	0.7
	Carpet	2000 x 3000mm Total m ² = 6	0.4
	Wooden shutters over windows (four sets)	1500 x 1000mm Total m ² = 6	0.23
Four	Acoustic ceiling tiles	8220 x 7060mm Total m ² = 58.033	0.7 (Class C)
	Back wall acoustic panel (polyester fibre), 10 panels	1200 x 6000mm Total m ² = 7.2	0.7
Five	Acoustic ceiling tiles	8220 x 7060mm Total m ² = 58.033	0.7 (Class C)

	Back wall acoustic panels (polyester)	1200 x 8220mm Total m ² = 9.8	0.7
Six	Acoustic ceiling tiles	8220 x 7060mm Total m ² = 58.033	0.7 (Class C)
	Pin boards on back wall covered in felt (4 panels)	1200 x 1500mm Total m ² = 1.8	0.7
	Book cases	5000 x 340mm Total m ² = 1.7	0.23
	Egg crates (8)	100 x 120cm Total m ² = 0.012	0.4
	Curtains (polyester)	1000 x 1900mm Total m ² = 1.9	0.7
Seven	Acoustic ceiling tiles	8220 x 7060mm Total m ² = 58.033	0.7 (Class C)
	Back wall acoustic panels (polyester fibre)	8220 x 900mm Total m ² = 7.398	0.7
	Carpet	2000 x 3000mm	0.4

		Total m ² = 6	
	Curtains (four)	1500 x 1000mm Total m ² = 6	0.7
Eight	Acoustic ceiling tiles (100% ceiling coverage)	8220 x 7060mm Total m ² = 58.033	0.7 (Class C)
	Back wall acoustic panels (foam) Ten panels	1200 x 600mm Total m ² = 0.72	0.7
	Transparent blinds (four)	1500 x 1000mm Total m ² = 1.5	0.58
	Carpet	2000 x 3000mm Total m ² = 6	0.7
Nine	Bean Bags (six)	400-500 mm in diameter	Bean bags can reduce amplitude of vibration by 80-90% = 0.85 NRC
	Carpet (two)	2000 x 3000mm	0.4

		Total m ² = 6	
	Pinup space (cork)	6576 x 1130mm Total m ² = 7.319	0.7
	Dado Rail (upholstery)	1000 x 8220mm (front and back) 1000 x 7060mm (side wall) 1000 x 6240mm (side with door) <u>Total m² =</u> Front wall: 8.22m ² Back wall: 8.22m ² Side wall: 7.06m ² Side wall (with door): 6.240m ²	0.7
	Curtains (four)	1500 x 1000mm Total m ² = 6	0.7
Ten	Acoustic Ceiling Tiles (2/3 ceiling	Option 1: 1/3 reflective tile	0.8 (Class A)

	coverage)	2/3 Class A (38.666 m ²)	
	Back wall acoustic panel	1000 x 8220mm Total m ² = 8.22	0.8 (Class A)
	Curtains (four)	1500 x 1000mm Total m ² = 1.5	0.7
	Carpet floor OR Vinyl Floor (100% coverage)	8220 x 7060mm Total m ² = 58.033	0.4

The materials’ surface areas were calculated by the measurements provided by the participants during phase two. The NRC rates were obtained either from the participants themselves or by contacting the companies that sell the materials suggested by the participants. This was researched and discussed with an acoustic engineer. The numerical data in Table 4.8 were inserted into the Sabine formula for calculation. The following calculations provided the post-acoustic treatment reverberation time as well as the overall reverberation time improvement shown in Table 4.9. The abbreviation, RT, in the formula refers to reverberation time. The following formula is the Sabine reverberation time formula, this was used to calculate the reverberation time post-acoustic treatment.

$$RT60 = \frac{V}{S} \frac{0.161}{\alpha}$$

Table 4.9

Pre- and post-acoustic treatment reverberation times (seconds) and the reverberation time improvement (seconds).

Participant	Pre-acoustic treatment reverberation time (seconds)	Post-acoustic treatment reverberation time (seconds)	Reverberation time improvement (seconds)
1	1.4	0.808	0.592
2	1.4	0.441	0.959
3	1.4	0.746	0.653
4	1.4	0.239	1.162
5	1.4	0.395	1.005
6	1.4	0.396	1.003
7	1.4	0.385	1.015
8	1.4	0.373	1.027
9	1.4	0.513	0.887
10	1.4	0.313	1.087

As seen in Table 4.9, Participant 4 achieved the lowest reverberation time of 0.239 seconds. However, from a cost-effective perspective, Participant 2 achieved a reverberation time of 0.441 seconds with the least amount of acoustic intervention, as seen in Table 4.8.

A Wilcoxon matched paired-signed rank test was conducted to determine whether the associated reverberation times to the post-acoustic treatment suggestions were significantly better than the pre-acoustic treatment reverberation time. The Wilcoxon matched pairs signed rank test results indicated that the post-acoustic reverberation times were statistically significantly better than the pre-acoustic reverberation time, $z = 0$, $p < 0.05$. In Figure 4.27, the results indicated that despite the price of the interventions designed by the participants, the reverberation times had significantly improved following the implementation of the acoustic treatment suggestions that belonged to each of the participants.

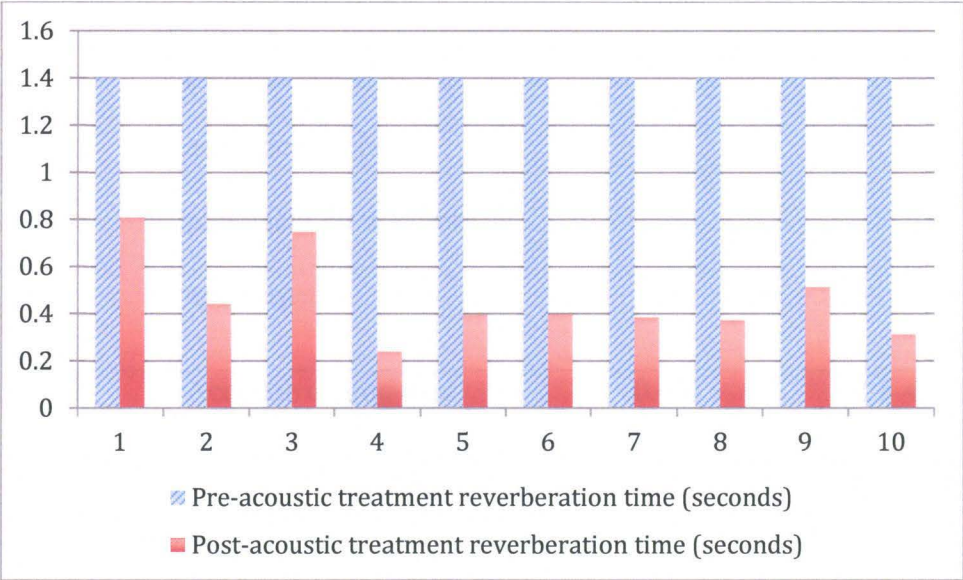


Figure 4.27. A paired bar graph displaying the statistically significant differences between the pre- and post-acoustic treatment suggestions reverberation times (seconds).

4.2.1.2. *Exploration between the post-acoustic treatment reverberation time (seconds) and the estimated price (ZAR) to implement the acoustic treatment.*

Table 4.10

Reverberation time (seconds) post-acoustic treatment and the estimated total price of the acoustic treatment considerations.

Participant	Summary of materials chosen	Reverberation time post acoustic treatment (seconds)	Estimated total price (ZAR) of acoustic treatment design
1	Ceiling absorption panels, back wall acoustic panels, plexiglass on windows, and carpets.	0.808	R 10 570 .10
2	Acoustic ceiling tiles	0.441	R 8 494
3	Acoustic islands, back wall acoustic panels, carpet, and wooden shutters.	0.746	R 9 014 .70
4	Acoustic ceiling tiles and back wall acoustic panels.	0.239	R 12 110 .53 (glass wool)
5	Acoustic ceiling tiles	0.395	R 18 506 .22

	and back wall acoustic panels.		
6	Acoustic ceiling tiles, pin boards on back wall, bookcase, egg crates, and curtains.	0.397	R 10 615
7	Acoustic ceiling tiles, back wall acoustic panels, carpet, and curtains.	0.385	R 15 119 .20
8	Acoustic ceiling tiles, back wall acoustic panels, blinds, and carpet.	0.373	R 13 519 .20
9	Bean bags, carpet, cork boards, dado rail, and curtains.	0.513	R 13 797 .80
10	Acoustic ceiling tiles, back wall acoustic panels, curtains, and carpet or vinyl flooring.	0.313	R 22 218 .52

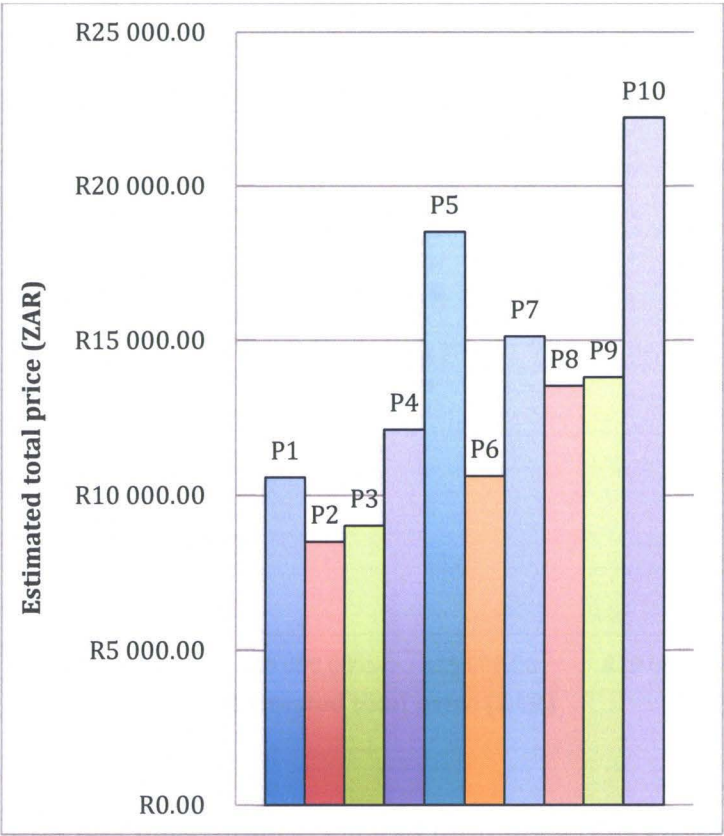


Figure 4.28. Bar graph illustrating the estimated total price (ZAR) of each participant’s (P) acoustic treatment considerations for the example classroom.

According to Table 4.10 and Figure 4.28, the cheapest acoustic treatment design with the highest effectiveness was considered by Participant 2, with an estimated total price of R 8 494. Participant 2 considered only treating the ceiling to achieve a reverberation time of 0.441 seconds. The most expensive acoustic treatment design with the highest effectiveness was considered by Participant 10, with an estimated total price of R22 218. 52. The purpose of this study was to explore the considerations for low-cost and effective acoustic treatments for an existing classroom. Therefore, Participant 2’s consideration seems to be the most feasible option based on the estimated total price and effectiveness of improving the reverberation time.

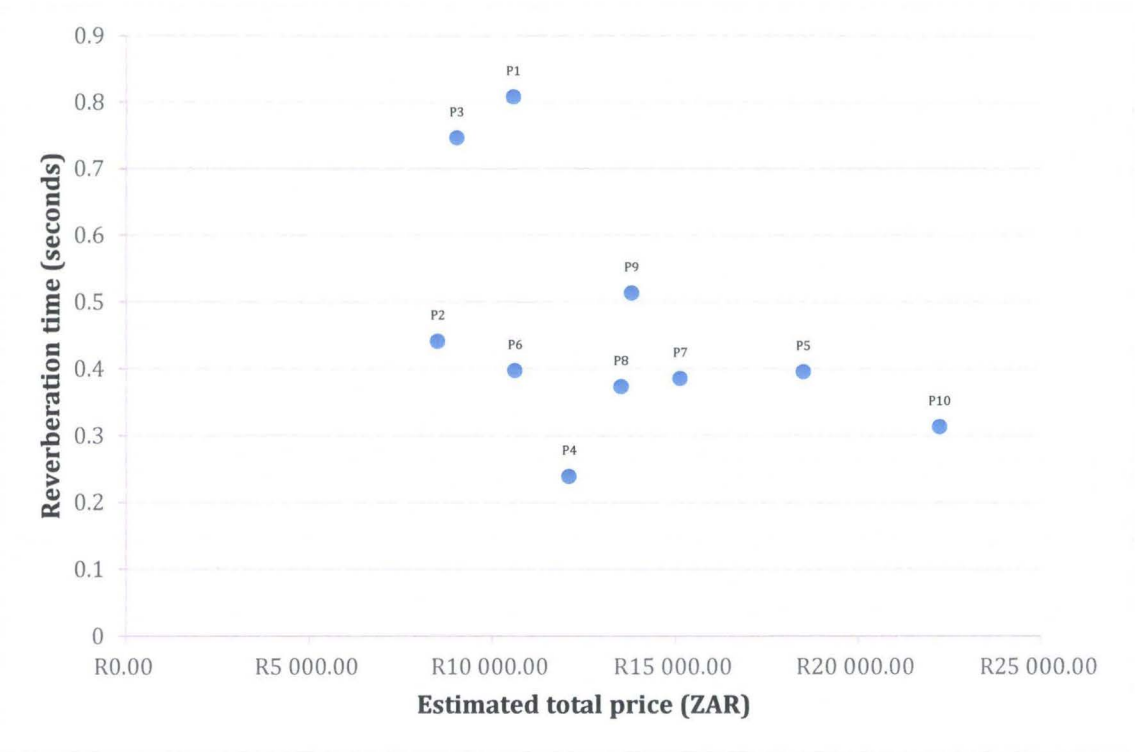


Figure 4.29. Scatter plot illustrating estimated total price (ZAR) to reverberation time (seconds) post-acoustic treatment of the example classroom.

A Pearson’s product-moment correlation coefficient was computed to assess the relationship between (variable one) reverberation time (seconds) following acoustic treatment and (variable two) the estimated total price (ZAR) associated to each reverberation time (Figure 4.29). The outliers, participant one and four were left out for the calculation to ensure the results would not be skewed (Figure 4.29). There was an insignificant, negative, linear, and moderate correlation between the two variables, $r = -0.595$, $n = 8$, $p = 0.119$. The researcher used an ANOVA to run a regression in order to determine the p-value, this is shown in Table 4.11.

Table 4.11

One-way Analysis of Variance used to run a regression to determine p-value.

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Regression	1	0.045	0.045	3.286	0.119
Residual	6	0.082			
Total	7	0.127			

This allowed the researcher to determine whether there was a significant relationship between the price of acoustic treatments and the associated reverberation time, $p = 0.119$ and $p > 0.05$ meaning that this relationship was insignificant. A scatterplot summarizes the results above (Figure 4.29). Overall, there was an insignificant, negative, linear, and moderate correlation between the price of acoustic treatment suggestions and the associated reverberation time. Increases with the price of acoustic treatments were correlated with decreases in reverberation time.

The insignificant relationship between the price of acoustic treatments and reverberation time post-acoustic treatment proves that it is not necessary for acoustic treatments to be expensive in order to be effective. The results show that one can acoustically treat a classroom on a budget and still achieve an appropriate reverberation time. Participant 2 seems to be the most ideal placement in the scatter plot. The reverberation time has improved significantly and the price is the lowest in its surrounding acoustic suggestion outputs. The insignificant moderate correlation explains that one can achieve an appropriate reverberation time on a budget.

Table 4.12

Table of low-cost materials that can be bought in South Africa.

Material Type	Estimated Price (ZAR)	Source
Corkboard	R215 2440x1220x13mm	Builders Warehouse
Felt	R65 per m ²	https://www.chamdor.com
Fabric (linen for panels)	R17, 18 per m ²	https://www.chamdor.com
High density foam	R80 500x500x50mm	https://www.chamdor.com
Polyester fibre (4kg)	R420 per m ²	https://www.chamdor.com
Timber	R51, 65 38x38x6000mm	www.poleyard.co.za
Ecophon Wall Panel	R1750	Ecophon
Weather strips for door and windows	R42 (for 5m)	Builders Warehouse
Acoustic tiles: OwaFutura/ OwaConstillation (Grid and tile – Class C;	R145 per m ²	OWA Acoustics

NRC 0.7)		
Acoustic tiles: Ecophon (Only tile – Class A; NRC 0.7)	R148 per m ²	Ecophon

Based on the above information provided by the participants, Table 4.12 was developed. The material price list (Table 4.12) contains the most effective and low-cost options based on this study’s results as well as the location of the materials. This table can be used together with Figure 5.1 as a guideline when acoustically treating an existing classroom. Both these resources could assist the involved professionals to have ease of access to information about classroom acoustics in the South African context.

Chapter 5: Discussion

This study primarily focussed on architects' and acoustic consultants' low-cost yet effective considerations for improving classroom acoustics. The research focussed on the following primary aim: To obtain architects' and acoustic consultants' low-cost considerations to acoustically treat the example classroom. The research focussed on the following secondary objectives: firstly, to determine the participants' reasoning for their considerations to acoustically treat the example classroom via drawings and semi-structured interviews; secondly, to determine the low-cost considerations to acoustically treat the example classroom by utilising the Sabine equation for reverberation times. The researcher focussed on this topic as there seems to be limited information available on low-cost yet effective strategies to acoustically treat existing classrooms in the South African context.

5.1. First Secondary Objective: The Participants' Reasoning for their Considerations to Acoustically Treat the Example Classroom

The participants were requested to consider low-cost yet effective acoustic treatments for the example classroom. This was achieved by drawing on images that represented the example classroom and simultaneously participating in a semi-structured interview. All ten of the participants began with designing acoustic treatments for the internal acoustics of the example classroom, in order to improve the reverberation time. Internal acoustics were focussed on due to the ease of implementation of materials. By adding materials into the example classroom the reverberation time may improve, whereas changing the structure of the example classroom may improve the ambient noise level due to sound insulation. This was also influenced from a financial perspective, as adding materials seems to be cheaper than changing the structure of the example classroom. With this, the participants explained that there are various ways to implement absorption into a space with a wide range of costs

and therefore it may be easier to implement into a low-cost project of acoustically treating the example classroom. Participant 7 mentioned that by improving on the internal acoustic conditions of a classroom it has a knock-on effect on the ambient noise level as the behaviour of the children and teachers should change with an improvement in acoustics, for example, there may be a quieter environment and therefore less shouting.

Despite the financial drive to treat the internal acoustics for reverberation time instead of acoustically treating for ambient noise levels, the literature shows how treating reverberation time is more beneficial than treating ambient noise levels in relation to speech recognition and intelligibility. As mentioned in the literature review, a number of studies have shown that improving reverberation times in a classroom has a much greater effect on speech intelligibility than improving the ambient noise levels (Hazrati & Loizou, 2012). The reason for this is explained through the science of noise and the effect it has on speech intelligibility. For example, when there is excessive reverberation time it causes overlap masking. Overlap masking is when the reverberant energy of a preceding phoneme overlaps the following phoneme (Kokkinakis & Loizou, 2011). This is particularly relevant for low-frequency consonants that precede a high-frequency consonant (for example, vowels) (Kokkinakis & Loizou, 2011; Hazrati & Loizou, 2012). This may cause major degradation of speech intelligibility. A study conducted by Kokkinakis and Loizou (2011), found that with a reverberation time of 1.0 seconds the mean intelligibility scores dropped by 60% in a quiet environment. This means that within a quiet environment learners were hearing 40% of what the teacher was saying. A study by Nelson, et al. (2003) shows that with a general increase of background noise speech intelligibility can drop by 50%. The learners' speech intelligibility was less affected with an increase in noise than when reverberation times were increased. Another study conducted by Kokkinakis, et al. (2011) showed that with a general increase in reverberation time word recognition can drop from 90% to 20%. With regard to ambient

noise levels, the noise masks the weak syllables but is not dependent on the energy of the preceding segments or consonants (Nabelek, et al., 1989). Gelfand and Silman (1979) suggest that performance in noise is related to the reverberant energy that predicts performance in reverberation, meaning that the effects of noise are worsened in reverberant spaces. The claim of prioritising acoustic treatments for reverberation time rather than ambient noise levels was supported by the literature.

The example classroom had an excessive reverberation time of 1.4 seconds, which makes one wonder what the learners in this environment were hearing with poor reverberation time and an ambient noise level average of 70.8dBA. These measurements of reverberation time and ambient noise levels are considered inadequate according to international and national standards.

As mentioned in the literature review, the American Speech-Language-Hearing Association (ASHA) recommend that reverberation time should not exceed 0.4 seconds, and the ambient noise level in an unoccupied classroom should be 30 – 35dBA (ASHA Working Group on Classroom Acoustics, 2005). Crandell & Smaldino (2000) recommended that reverberation times should be around 0.4 seconds for learners with learning difficulties, and Peng (2014) recommended that reverberation time should be around 0.6 seconds for learners who are being taught in a second language. As mentioned in the literature review, international standards are all in agreement with the guidelines for reverberation times, below 0.6 seconds, and ambient noise levels in the classroom, at 35dBA. In South Africa, the Department of Education released guidelines in 2012 for reverberation times of 0.6 to 0.7 seconds, and background noise levels of 40 – 50dBA. The SANS 10130 (2008) recommends that ambient noise levels should not exceed 35dBA in an unoccupied space, however, there is no guideline referring to reverberation times. SANS 10400 (2010) does not have any guidelines for acoustic requirements and does not deem them as being necessary for comfort

and convenience, which the literature can quite clearly disprove, it provides reason as to why acoustic conditions are so overlooked (Van Reenen & Karusseit, 2017).

As mentioned in the literature review the effects of poor acoustic conditions in a classroom are well understood. Literature illustrates these negative effects on language processing abilities, academic performance, speech intelligibility, speech perception, and the wellbeing of children in school (ASHA, 2015; Crandell & Smaldino, 2000; Dockrell & Shield, 2004; Dockrell & Shield, 2006; Erler et al., 2008; Klatte et al., 2010; Yang & Bradley, 2009). The participants seemed to be immediately aware of the negative impact that poor acoustic conditions could have on the learning and teaching experience in a classroom. However, their knowledge and use of acoustic norms were poor. This result was consistent with the results obtained in a study conducted by Ryder (2017), where architects were interviewed on their knowledge of acoustics norms and the implementation thereof in classrooms that they may have been involved in. Ryder (2017) found that the architects who participated in her study were not familiar with the acoustic recommendations set by the national government due to reasons such as, vague standards and regulations, as well as financial and resource limitations.

5.1.1. Design considerations for the treatment of reverberation time.

5.1.1.1. Acoustic treatment of the ceiling.

Implementing acoustic treatment on the ceiling was suggested by nine out of the ten participants. Two out of ten participants that chose to use acoustic ‘islands’ or ‘clouds’ explained that it would be cheaper to home-make the acoustic ceiling panels and install them onto the existing ceiling. However, seven out of ten participants who chose to cover the ceiling with absorptive acoustic tiling explained that it would be cheaper to install acoustic ceiling tiles, even at a Class C level with an NRC rating of 0.7. This was because a large

absorptive surface area was introduced at a much cheaper price than adding many other materials to try and achieve the same reverberation time. As Participant 1 mentioned, the more absorption you bring into a space the lower the reverberation time will be. This is where low-cost and efficiency may show high relevance. In the quantitative results of this study (which will be delved into further on) one can understand that with the simple implementation of an acoustic ceiling tile with 100% coverage of the ceiling, Participant 2 achieved a reverberation time of around 0.4 seconds (with a Class C ceiling tile with an NRC rating of 0.7). As seen above in the international standards, many countries opt for a reverberation time that is less than 0.6 seconds, especially for classrooms that host learners that may have learning difficulties (Crandell & Smaldino, 2000) and those who are being taught in a second language (Peng, 2014). There are many studies in the literature that indicate the improvement of reverberation time with the installment of an acoustic ceiling. A study by Blomkvist, Erikson, Theorell, Ulrich, and Rasmanis (2005), was conducted in a small ward in a hospital where Class A ceiling tiles from Ecophon were installed and the reverberation times improved drastically, the reverberation time halved from 0.8 seconds to 0.4 seconds. An article published by the National Deaf Children's Society (2016) reports that replacing a normal ceiling with acoustic tiles could be a cost-effective way of improving the reverberation time. An assessment of the efficiency of acoustic ceiling tiles was conducted by Dr Andrew Poynter (van Emden & Becker, 2018), who found that reverberation times and noise levels had improved significantly following the installment. Acoustic ceiling tiles absorb sound and reduce the amount of sound transmitted to other spaces nearby (Binggeli, 2008). They are used to reduce reverberation and sound transmission in a space (Binggeli, 2008). According to Ecophon (2018), the use of a sound absorbing ceiling can improve the reverberation, sound propagation, and the sound levels in a classroom. According to Cox and D'Antonio (2009), one of the most ideal places to add absorption into a space, to improve the

acoustic conditions, is on the ceiling. Paulo and Coelho (2009) recommended that covering the ceiling area with sound absorption materials can improve the reverberation within a space. DiSarno, Schowalter, and Grassa (2002) report that by making physical modifications to the ceiling, the signal-to-noise ratio should improve as the ceiling makes up around 30% of the classrooms surface area and therefore should make significant improvements to the acoustics of the classroom.

5.1.1.2. Acoustic treatment of the back wall.

Nine out of the ten participants opted to have absorptive panels installed on the back wall of the example classroom. The participants mentioned that the reason for this installation would be to add in more absorptive surface area into the classroom in order to reduce the reverberation time as well as prevent the slap-back echo off the back wall. Many of the participants opted for the high-density polyester filling to use as the absorptive material inside the panels as it is safe from a health point of view and is cheap on the market. Three out of ten participants mentioned that mineral wool such as fibreglass can float around in the environment and be inhaled by the learners, therefore they opted for polyester fibre. According to the World Health Organization (as cited in Woolley, 2016; Kubba, 2017), the US National Toxicology Program (as cited in Woolley, 2016; Kubba, 2017), and the National Cancer Institute (as cited in Woolley, 2016; Kubba, 2017) fibreglass has been listed as a probable human carcinogen (Adams & Gimbel, 1994).

Two of the ten participants mentioned that they would go for a home-made option of creating absorptive acoustic ceiling panels or wall panels by working hand-in-hand with a building contractor or a basic carpenter. The participants emphasised that by combining a number of materials with a very simple structure, anyone could implement this design into creating their own acoustic panels for either the ceiling or the wall. As part of the ecological

framework, one can note the opportunity to create jobs or work opportunities in this particular setting. The parents of the learners can assist with the construction of these home-made acoustic ceiling or wall panels. This creates inclusion of the local community and supports those who may be in need of employment. The Rural Education Policy supports and encourages projects that recognise the role of the community, this creates a sense of belonging for the school and the community which further develops connectedness among those involved (Rural Education Draft Policy, 2017).

According to Ecophon (2018), the use of vertical acoustic panels can enhance speech clarity: the more sound absorption there is the lower the reverberation and noise levels will be. These wall panels also avoid the chance of having a flutter echo (similar to a slap-back echo) (Ecophon, 2018). Knecht, Nelson, Whitelaw, and Feth (2012) suggest that using absorbing panels in a classroom can improve the overall acoustics of a room. One solution to a reverberant space is to add acoustic absorbers (Cox & D'Antonio, 2009) as this reduces the sound energy from reflecting in the room. One of the places for absorption is high up on the walls (Cox & D'Antonio, 2009). The British Society of Audiology (2011) suggests improving acoustic conditions within a classroom by using acoustic paneling on the walls. The American Speech-Language-Hearing Association (2018) suggest placing soft materials on the wall or using corkboards as absorptive panels on the walls to improve the acoustic conditions. DiSarno, Schowalter, and Grassa (2002) report that making physical modifications on the walls can improve the signal-to-noise ratio.

Only one participant mentioned the method of using egg crates to reduce the reverberation time in the example classroom. Participant 6 mentioned that the egg crates should be placed on the back wall for sound absorption. Literature shows that there are very limited benefits of egg cartons for the improvement of acoustic conditions (Moss & Wiesenfeld, 1995). Egg cartons do not absorb classroom noise, however, they may assist in

absorbing excess reverberation (DiSarno, Schowalter, and Grassa, 2002; Crandell, Smaldino, & Flexer, 1995).

5.1.1.3. Acoustic treatment using carpets/flooring.

Carpets or a change in flooring were suggested by six out of ten of the participants and four out of ten of the participants did not consider changing the flooring. There is a lot of literature that supports the use of carpets to improve the acoustic conditions in a space. The British Society of Audiology (2011) and American Speech-Language-Hearing Association (2018) suggest that using carpets has advantageous influences on the reverberation time in a room. Both Ramma (2007) and Stonestreet (2016) found that curtains in combination with carpets are effective and are low-cost sound absorbing materials which can reduce reverberation times in an unoccupied classroom. Carpeting proved to be effective in reducing reverberation in the 2000Hz to 8000Hz range (Stonestreet, 2016). However, Participant 10 made an interesting statement regarding the need for appropriate flooring in a classroom space. The participants who opted for carpets expressed that the carpet may not have that much of a significant impact on the reverberation time or ambient noise levels, but it will reduce the noise of furniture moving or people walking. This was supported by an article by Seep et al. (as cited in, DiSarno, Schowalter, & Grassa, 2002), that states that carpets actually have very little effect on sound absorption. The floor makes up around 30% of the classroom's surface area and therefore installing carpets on the floor can help reduce the reverberation time (DiSarno, Schowalter, & Grassa, 2002).

5.1.1.4. Acoustic treatment using curtains.

Curtains were considered to increase softness into the classroom to act as more surface area for absorption by five out of the ten participants. The participants who considered the curtains for the example classroom acknowledged that the acoustic benefits of

the curtains were limited, yet adding any sort of soft material in the example classroom would assist with absorbing and redirecting sound towards the acoustically treated roof for absorption. The British Society of Audiology (2011) and American Speech-Language-Hearing Association (2018) suggests the use of curtains to improve the overall reverberation time. Research has concluded that curtains are effective and are low-cost sound absorbing materials which can reduce reverberation times in an unoccupied classroom (Stonestreet, 2016; Ramma, 2007; Cowan, 2007). Participant 7, a participant who has done projects in the classroom setting explained that the gap between the window and the curtain is important as this is where a lot of the sound energy is dispersed and thereafter absorbed, and therefore less sound energy is being released into the classroom area where teaching is taking place. This was confirmed in the literature, curtains hung with appropriate airspace between the window and fabric are effective in reducing reverberation between the 250Hz to 1000Hz ranges (Stonestreet, 2016; Cowan, 2007; Everest & Pohlmann).

5.1.1.4. Acoustic treatment using shelving and other absorptive furniture.

A number of the participants considered using furniture made of natural materials, such as wood, to be used as sound absorption materials in the example classroom. As mentioned by Participant 10, the furniture will diffuse the sound energy by breaking the sound reflection and redirecting it to the acoustically treating ceiling for absorption. Ecophon (2018) and Nilsson, Andersson, and Chigot (2006) report that furniture can be used to redirect sound energy towards the sound absorbing ceiling as the furniture scatters or diffuses the sound, this diffusion of sound energy towards absorptive materials reduces reverberation time. According to Chou and Hsia (2013), furniture causes multipath sound propagation and scattering due to the sound being absorbed or reflected by furniture. DiSarno, Schowalter, and Grassa (2002) report that functional furniture such as bookshelves can be placed in strategic positions to reduce reverberation.

5.1.2. Design considerations for the treatment of the ambient noise level.

5.1.2.1. Too expensive to conduct sound insulation.

As per Table 4.2, many of the participants mentioned that it would be a very costly exercise to make changes in order to improve the ambient noise level as this would require sound insulation. According to the participants, sound insulation involves changes in the structure of the example classroom which is very expensive. Sound leakage is caused by poorly insulated classrooms that can lead to external noise entering the classroom and causing disturbances amongst the learners and the teacher (Chermak & Musiek, 2014). The classroom walls, ceiling, and floors would need to be acoustically upgraded to achieve sound insulation (Chermak & Musiek, 2014). Sound insulation is necessary to prevent intrusion from external noise sources, which may have implications for the ventilation system: if windows and doors are the main source of ventilation they would need to be replaced with a mechanical ventilation system, such as an air conditioner which can be very costly (Asselineau, 2015). According to the participants, replacing doors and windows with a higher spec for sound insulation is not an option for low-cost considerations. The structure of the walls greatly affects the quality of sound in a space. In South Africa, the walls of schools are usually constructed out of thin and lightweight materials to maintain a budget-friendly project (Hollander & de Andrade, 2013; Gaines, Bourne, Pearson, & Kleibrink, 2016). Thin walls cause poor sound insulation, whereas a thicker construction of the walls would dampen the sound's ability to travel through the walls, but this may come at a cost (Gaines, et al., 2016).

5.1.2.2. Treating the windows and the door for sound insulation.

According to the participants, sound insulation is a complex exercise to implement into an already existing structure. It requires insulating all possible openings in the structure to ensure that sound cannot enter when these openings are closed. Flanking of noise, noise

that enters through the windows or door from other classrooms is highly common in classrooms. Therefore the participants suggested that rubber seals should be placed on the edge of the windows and door to ensure a solid seal is formed between the frame of the window and the frame on the wall. Windows and doors are well known for being the weakest links for acoustics between rooms and external noise. If sound insulation is desired there needs to a good positive seal for the doors and windows when they are closed (Ashcroft, 1992; Crocker & Kessler, 2018; Hopkins, 2007; Liu, Zhang, & Liu, 2017). According to Crocker (1998) and Ashcroft (1992), seals and weatherstripping are essential to improve sound insulation to about 10-20dB when the doors and windows are closed and if there is a good fitting seal. Participant 1 suggested adding plexiglass to the windows, as sound insulation does not necessarily improve when the thickness is added to the single-glazed window (Crocker, 1998). However, some improvement will be seen as mass has been added to create a thicker surface for the sound to travel through (Crocker, 1998; Hopkins, 2007). Double-glazed windows are highly beneficial as the air gap between the two pieces of glass increase the sound insulation, specifically at lower frequencies, however, this is not cost effective (Ashcroft, 1992; Crocker & Kessler, 2018; Hopkins, 2007). Closing the windows and doors is not an ideal fix for sound insulation in the South African context as mechanical ventilation is not always an option due to cost, therefore, windows and doors are used for ventilation purposes. If the windows and doors are not closed, the seals on them will not be put to use and sound insulation will not be achieved.

5.1.2.3. Shutters or curtains.

Curtains were not only considered for the improvement of reverberation time but for the improvement of ambient noise levels too. Participants mentioned that they would use the curtains to absorb the excess sound energy in the example classroom. Sound absorption is important to consider, by using effective sound absorbing materials such as curtains, the

sound levels can be reduced (Phillips & Griebel, 2003). Acoustical curtains are heavy vinyl quilts that can reduce ambient noise levels by 5 to 10 decibels, and are highly expensive (Shane, Kandil, & Schexnayder, 2012). Heavy curtains are known as membrane absorbers that absorb lower frequency sounds rather than high-frequency sounds (Thomas, 1999; McCauley, 2001). If acoustic curtains only make a difference of 5 decibels to 10 decibels, then polyester linen curtains probably would not make a difference at all for ambient noise levels. They are typically used for the reduction of reverberation time. Thicker materials absorb longer wavelengths (low frequency) better than thin ones, as the effectiveness of the material is dependent on the thickness (Thomas, 1999). To improve the efficiency of curtains, one can pleat them as this would increase the surface area and therefore noise transmission would be reduced, this is a less expensive option (Bridger, 2003). Participant 3 mentioned the creation of wooden shutters that could act as a barrier for the window for when physical education is occurring outside the classroom. This design may not be ideal for improving ambient noise levels as there are many leaks in the structure, but the materials of the shutters themselves will allow for some absorption of the reverberation (Phillips & Griebel, 2003).

5.1.2.4. Replacing the fans.

Two of the participants strongly considered the replacement of the old racketing fans. According to Participant 10, noise generated by the fan can cause a lot of distraction and can be very difficult for the learner to tune out in order to hear the teacher. Fans found typically in the classroom have noise that affects learners concentration (Monson, Sommerfeldt, & Gee, 2007; Kassuto, 2016; Almaguer, 2015). Even though the noise level from a fan is not high enough to cause damage to one's hearing, research shows that it has a negative impact on a learners' well-being in the classroom (Monson, Sommerfeldt, & Gee, 2007; Kassuto, 2016; Almaguer, 2015). Fans that racket are time-invariant due to the rotation of the blades (Monson, Sommerfeldt, & Gee, 2007). For learners that struggle with attention and tuning

out external noise, learning in a classroom with such a time-invariant noise can create a major barrier to learning (Monson, Sommerfeldt, & Gee, 2007). Participant 4 mentioned that it was not only noise that causes a barrier to learning but other conditions within the classroom too, such as temperature. Learners' satisfaction and performance rely on ambient attributes as well as air quality and temperature (Yang, Becerik-Gerber, & Mino, 2013). A study conducted by Wargocki, Wyon, Matysiak, and Irgens (2005) and Wargocki and Wyon (2006c), reported that a reduced temperature in the classroom by increasing ventilation increased learners' work rates. In warm weather, elevated temperatures should be avoided as it has a negative impact on a learner's educational attainment (Wargocki & Wyon, 2006a). A study showed that a learners' performance on schoolwork can be reduced by 30% if the indoor environmental conditions are not adequate (Wargocki & Wyon, 2012). Another study conducted in 2016 showed that inadequate thermal and air quality conditions can reduce performance by 15-30% for children (the learners) and 5-10% for adults (the teacher) (Wargocki & Wyon, 2016). Low ventilation rates cause a negative effect on a learner's attention, memory, and concentration as well as on the teacher's ability to teach (Bako-Biro, Clements-Croome, Kochhar, Awbi, & Williams, 2011). Air quality and temperatures in classrooms are very important in the learning process: they should be given as much attention as teaching materials and methods (Wargocki & Wyon, 2006b; Van Tonder et al., 2016). Participant 4 mentioned that it was imperative to have air-flow within the classroom and the windows are not ideal for this purpose as it creates greater vulnerability to external noise inside the classroom.

5.1.2.5. Improving ambient noise levels to increase speech intelligibility.

Two participants mentioned that the higher the ambient noise level was the less speech intelligibility will be. It is commonly known that speech intelligibility is reduced when there is background noise, especially for those that may have learning difficulties or a

hearing loss (Wang et al., 2009; Crandell & Smaldino, 2000). Fluctuating noise, such as traffic or noise from the sports field, and competing speech, such as other classrooms being audible, causes a much higher disturbance (Festen & Plomp, 1990; Peters et al., 1998; Wang et al., 2009; Hollander & de Andrade, 2013). A study conducted by Bradley and Yang (2009) showed that speech intelligibility is highly influenced by the signal-to-noise ratio in the classroom. As mentioned previously, Nelson, et al. (2003) also conducted a study that showed, with an increase of background noise, speech intelligibility drops by as much as 50%. With regard to ambient noise levels, the noise masks the weak syllables but is not dependent on the energy of the preceding segments or consonants (Nabelek, et al., 1989). This could cause major interference with speech intelligibility and cause a barrier to learning in the classroom (ASHA, 2015; Crandell & Smaldino, 2000; Davis, 1991; Johnson, 2001). Impaired academic performance is common as learners have to have increased listening efforts which requires more cognitive resources to allow availability of storage and processing of the spoken information (Klatte, et al., 2010; Johnson, 2001; Downs & Crum, 1978; Hollander & de Andrade, 2013; DiSarno, Schowalter, & Grassa, 2002). Therefore an improvement in ambient noise levels will improve the signal-to-noise ratio and could prevent the above-mentioned effects of noise on learners.

The participants expressed that by improving ambient noise levels it has a knock-on effect on how the teachers teach. This is explained by Ecophon (2018) and is called a psychological reaction. The physical reduction of sound pressure levels in a room results in additional sound reduction through a psychological reaction to the change in environment, such as teachers speaking more quietly and learners being quieter (Ecophon, 2018). The reduction in noise in one classroom could reduce the noise travelling to the adjacent classroom, which in turn creates a quieter learning environment for all the classrooms.

5.1.2.6. Rearrangement of the classroom.

One of the participants considered rearranging the seating layout in the classroom by placing the learners' backs towards the sports field and them facing the recreational area. Literature shows that seating arrangements in the classroom can influence how learners respond to the acoustics in the classroom. Rearranging desks to minimize teacher and student distances can improve how the teacher teaches and how the learners learn (Siebein, Gold, Siebein, & Ermann, 2000). A study conducted by Guardino and Antia (2012) indicated that a change in seating arrangements showed a functional relationship between the physical environment and an increase in academic interaction and a decrease in distraction. Seating arrangements can be used to limit distractions since the sports field is on the right side of vision of the learners, this participant wanted to change the seating arrangement so that their backs were towards the sports field (Effective Classroom Seating Arrangements, 2016). This will keep distractions out of the learners' line of vision (Effective Classroom Seating Arrangements, 2016; Wannarka & Ruhl, 2008). Sitting with one's back towards noise reduces speech intelligibility difficulties as the teacher's voice will be the only signal directed towards the learners without competing noise coming from the same direction (Chester, 2017).

5.1.2.7. Flooring.

Participants mentioned that the sound of metal furniture on the floor generates a lot of noise. Participant 10 shared that, it is not necessarily about sound absorption but rather ensuring that sound is not generated by furniture moving on the floor. Another suggestion was using rubber footing on the legs of the chairs and tables. Noise from footfall and furniture moving can be an issue in schools that have multi-stories, specifically if there are hard floor finishes (National Deaf Children's Society, 2016). Carpets or vinyl flooring are

used to acoustically treat the floor to reduce the noise produced from inadequate flooring material (National Deaf Children's Society, 2016; Cavanaugh, Tocci, & Wilkes, 2010). Sound treatments on the floor can improve reverberation as well as prevent noise generation (Cavanaugh, Tocci, & Wilkes, 2010; Hegarty et al., 1998). The acoustic floor dampens the noise made by moving chairs, tables, and people walking (Cavanaugh, Tocci, & Wilkes, 2010; Hegarty et al., 1998). The more absorbent the material is on the floor the more impact it will have on ambient noise (Peters, Smith, & Hollins, 2011). Although these considerations were suggested by the participants, they also mentioned that these solutions would only be implemented in the ideal situation of a limitless budget.

5.1.3. External treatment suggestions to improve internal acoustics.

5.1.3.1. Barriers around the school by the road and outside the classroom by the sports field.

The participants mentioned that the best way to treat ambient noise levels is to treat the source of the problem. Unfortunately, the road noise is very difficult to treat and therefore four out of the ten participants considered building a barrier around the school to reduce the noise from the road affecting the example classrooms learning environment. Trees were considered by three out of the ten participants and a brick wall by one of the participants. These were considered to be long-term solutions. The participants mentioned that they would consider placing a barrier outside the classroom on the side of the sports field to reduce the noise entering the classroom. The participants considered barriers such as hedges, trees, a soil berm, and a timber or brick wall. Although these considerations were suggested by the participants, they also mentioned that these solutions would only be implemented in the ideal situation of not having a budget.

Acoustic energy is attenuated, reflected, refracted, absorbed, or scattered by barriers along its path (Nilsson, Bengtsson, & Klæboe, 2015; Wenger, 1984). Tall timber or brick barriers can reduce noise by 2dB (Attenborough, Li, & Horoshenkov, 2007; Kotzen & English, 1999). Vegetation can be used for noise attenuation, mainly for lower and higher frequency noise, and should provide attenuation of around 6-8dB, however there is no benefit for mid frequencies (such as, traffic noise) (Attenborough, Li, & Horoshenkov, 2007; Kotzen & English, 1999; Nilsson, Bengtsson, & Klæboe, 2015). The low-frequency attenuation is due to the ground absorption being enhanced by leaves and branches that have fallen (Kotzen & English, 1999). The trees themselves provide absorption for high-frequency noise (Attenborough, Li, & Horoshenkov, 2007; Kotzen & English, 1999). Trees, hedges, solid fences, and berms can be helpful with absorbing sound (Jefferis & Madsen, 2005; Nilsson, Bengtsson, & Klæboe, 2015; Wenger, 1984;). The density of the barrier influences sound reduction (Jefferis & Madsen, 2005; Wenger, 1984).

5.1.4. Acoustic norms used by the participants.

Three of the participants did not know what the appropriate reverberation times and ambient noise levels were. This is not uncommon: a study conducted by Ryder (2017) showed the same results with architects who were unaware of norms for acoustics in classrooms. One out of the three participants was not aware that norms existed in South Africa. Two out of the same three participants were aware of the limited norms suggested by SANS, however, they practically used acoustic norms from Australia and New Zealand. The Association of Australian Acoustical Consultants Guideline for Education Facilities Acoustics (Association of Australian Acoustical consultants, 2010) guidelines for reverberation times are below 0.6 seconds, and ambient noise levels in the classroom, at 35dBA. According to Bistafa and Bradley (2000), in a quiet classroom speech intelligibility is maximised at 0.1 seconds and 0.3 seconds. However, speech intelligibility is 100%

possible with a reverberation time of 0.4 seconds to 0.5 seconds, and this is the recommended range (Bistafa & Bradley, 2000). As mentioned previously, the SANS 10130 (2008) recommends that ambient noise levels should not exceed 35dBA in an unoccupied space, however, there is no guideline referring to reverberation times. SANS 10400 (2010) does not have any guidelines for acoustic requirements. There is a general understanding that acoustics are necessary for comfort and convenience, which the literature can quite clearly disprove, which provides a reason as to why acoustic conditions are so overlooked (Van Reenen & Karusseit, 2017).

5.1.5. Personal experience.

One of the participants brought up the concern that clients are not willing to pay for acoustic treatments as they do not see it as a necessity. As Van Reenen and Karusseit (2017) mentioned, our own norms for acoustics are so limited that it provides a reason as to why acoustic conditions are so overlooked, especially since SANS 10400 (2010) does not have any guidelines for acoustic requirements and does not deem them being necessary for comfort and convenience.

Participant 2 mentioned the concept of ‘legacy architecture’: referring to this as architects who build for aesthetics and not necessarily the functionality of the building. This participant found that many buildings have significant issues with acoustics due to acoustics not being considered in the building plan of a construction project. This is supported by a study conducted by Ryder (2017): architects, the professionals who are involved in the design and building of these classrooms, are not familiar with the acoustic recommendations set by the government due to the unclear and vague standards and regulations which are provided for professionals to follow. Financial constraints are one of the reasons as to why architects allow acoustics to become an afterthought (Ryder, 2017). Another study conducted by Van

den Berg (2016) reported that during the design phase of a new construction project the architect rarely includes room acoustics. Despite the knowledge that architects may have on acoustic norms, their implementation of acoustics into their designs is poor. This suggests that professionals involved in the construction of a building are not implementing the laws despite the proven effects of inadequate acoustic conditions (Shield & Dockrell, 2003). These articles emphasised that there is a problem with the way architects design as it only focuses on the visual sense (Van den Berg, 2016).

It seems as though knowledge and experience will drive a professional to handle a project in a particular way. This shows that experience could be an important factor to managing an acoustic project.

5.1.6. Speech intelligibility.

A number of the participants expressed their opinions about the effects of poor acoustics on speech intelligibility. The reverberation in a classroom destroys the intelligibility of what the teacher is saying (Kokkinakis et al., 2011; Nabelek, et al., 1989; Gelfand and Silman, 1979). Poor acoustics can cause learners to hear only 30% of what the teacher is saying, and the rest they have to try figure out (Festen & Plomp, 1990; Peters et al., 1998; Wang et al., 2009; Hollander & de Andrade, 2013). As mentioned throughout the literature review, there are many negative effects that poor acoustics can have on learners of typical and atypical learning abilities. Four of the ten participants expressed that when there are poor acoustic conditions in a classroom it causes poor speech intelligibility which creates a barrier between the teacher and the learners receiving the teacher's lesson. A number of studies have supported what the participants expressed: learners who are only receiving a small portion of the teacher's voice tend to begin to behave inappropriately (Klatte, Bergstrom, & Lachman, 2013; Shield & Dockrell, 2003; Pratama & Nigmara, 2015). Four of the participants

mentioned that the learners get tired, distracted, and misbehave because they cannot overcome the poor acoustics conditions in the classroom. As mentioned previously, Participant 4 expressed that the fundamental part of education is communication: in a classroom communication is optimised with good acoustics.

The participants seemed to be well aware of the negative impact poor acoustics can have on speech intelligibility in the classroom. Since most classrooms in South Africa use a auditory-visual approach to teaching, speech intelligibility is vital to enhance the learning and teaching environment.

5.2. Second Secondary Objective: Post-Acoustic Treatment Reverberation Times (seconds) Calculated Using the Sabine Reverberation Equation, Based on the Participants' Low-Cost Considerations

The researcher focussed on the change in reverberation time instead of focussing on reverberation and ambient noise levels. Through the process of the semi-structured interview guide with the live drawings, many of the participants mentioned that ambient noise levels can only be improved by either changing the structure of the classroom or treating the source of the noise.

As mentioned in the literature review, the effect of reverberation time on speech intelligibility is much greater than ambient noise levels (Hazrati & Loizou, 2012; Whitmal & Poissant, 2009). Reverberation time has more of a negative effect on speech intelligibility than ambient noise levels in a learning environment. Gelfand and Silman (1979) suggest that performance in noise is related to the reverberant energy that predicts performance in reverberation, meaning that the effects of noise are worsened in reverberant spaces.

Due to this study focussing on low-cost yet effective ways to acoustically treat the example classroom, all ten of the participants focussed on treating reverberation times instead

of ambient noise levels. Because of this, the researcher chose to analyse the changes in reverberation times. Reverberation time is the most important parameter for describing the quality of a room (Neubauer & Kostek, 2001). This parameter is introduced by Sabine in the following equation:

$$RT60 = \frac{V 0.161}{S \alpha}$$

In order to explore the possible effect and benefit of these opinions and suggestions of the architects and the acoustic engineers from phase two, the Sabine reverberation equation was used. Each of the considerations was sized by the participants providing specific measurements. As part of the Sabine formula, each material considered needs a surface area and noise reduction coefficient (NRC). This was calculated by the researcher. The findings from phase two were analysed with the above mentioned Sabine equation and measurements such as reverberation times were measured in a pre- and post-processing of data. This allowed the researcher to determine, in a simulated acoustic situation, how the acoustics either improved, stayed the same, or worsened. Costing for each material was determined by participants providing cost prices of the selected materials and the researcher obtaining prices from different companies recommended by the participants (Table 4.10).

The numerical data from Table 4.8, surface area and noise reduction coefficient related to the materials chosen by the participants, were inserted into the Sabine formula for calculation. The calculations provided the post-acoustic treatment reverberation time (Table 4.9) as well as the overall reverberation time improvement.

Participant 4 achieved the lowest reverberation time of 0.239 seconds with the acoustic considerations for the example classroom. However, from a financial perspective, Participant 2 achieved a reverberation time of 0.441 seconds with the least amount of acoustic intervention. According to national and international acoustic norms, 0.4 seconds is

considered an appropriate reverberation time for learners of typical and atypical learning abilities (ASHA, 2005; Crandell & Smaldino, 2005; Peng, 2014; Department of Education, 2015; Acoustical Society of America, 2010; Association of Australian Acoustical Consultants, 2010; SANS 10130, 2008; SANS 10400, 2010; Bistafa & Bradley, 2000). Therefore, 0.4 seconds seems to be the most ideal reverberation time and anything lower than this may be unnecessary considering the emphasis of low-cost considerations to implement into the example classroom.

A Wilcoxon matched paired-signed rank test was conducted to determine whether the post-acoustic treatment considerations reverberation times were significantly better than the pre-acoustic treatment reverberation time. The Wilcoxon matched pairs signed rank test results indicated that the post-acoustic reverberation times were statistically significantly better than the pre-acoustic reverberation time, $z = 0$, $p < 0.05$. The results indicate that despite the price of the interventions designed by the participants, the internal acoustic qualities, specifically the reverberation times, had significantly improved following the implementation of the acoustic treatment suggestions that belonged to each of the participants.

A Pearson's product-moment correlation coefficient was computed to assess the relationship between reverberation time (seconds) following acoustic treatment and the estimated total price (ZAR) associated with each reverberation time. Overall, there was an insignificant, negative, linear, and moderate correlation between the price of acoustic treatment suggestions and the associated reverberation time. Increases with the price of acoustic treatments were correlated with decreases in reverberation time. The insignificant relationship between the price of acoustic treatments and reverberation time post-acoustic treatment proves that it is not necessary for acoustic treatments to be expensive in order to be

effective. The results show that one can acoustically treat a classroom on a budget and still achieve an appropriate reverberation time.

With the above information, the researcher could recommend a practical classroom design that is based on the study's report of reverberation time improvements, cost price, and acoustic norms based on international and national standards. With this, Participant 2 seems to have the most ideal design. The reverberation time has improved to an appropriate time (according to international and national acoustic norms) and the price is the lowest in its surrounding acoustic suggestion outputs. Participant 2 chose to treat 100% of the ceiling using a Class C ceiling tile, either OWAcoustic Futura or OWAcoustic Constellation have an NRC rating of 0.70 and costs R145.00 per m². A less expensive solution is to install absorbent ceiling tiles mounted in a T-bar grid (Cox & D'Antonio, 2009). From a cost-effective and efficiency point of view, this seems to be the most ideal design to improve the acoustics of the example classroom.

An important factor that Participant 2 brought up was that acoustic ceiling treatment is cheaper than buying a new computer or projector for a classroom. As mentioned in the literature review, the Department of Basic Education and the Department of Telecommunications came together to discuss the need for information communication technology (ICT) in schools for teaching and learning purposes, not only for administrative roles (Gina & Kubayi, 2016). A national long term goal includes introducing technology to each learner and teacher (Gina & Kubayi, 2016). As mentioned above, the cheapest acoustic treatment that achieved an appropriate reverberation time was calculated to be R8 494.00, as Participant 2 mentioned, this is cheaper than buying a new computer or tablet for a classroom. To understand a more extreme example, if the average amount of learners in a classroom is around 31 learners (Motshekga, 2012) one can say that it is essentially R274.00 per child in an average South African classroom. If we compare R274.00 to the price of a

tablet or computer per child or even per classroom, the maths speaks for itself. One can introduce resources, technology, and changes in teaching methods, but if the environment is not supportive to learners, especially those who may have learning difficulties or those that are second language English speakers, these advances may have very limited benefit due to the poor acoustic conditions in the classroom. The negative effects that are caused by poor acoustic conditions may not disappear when things such as teaching methods and technology are implemented in the classroom. The issue needs to be fixed at the source of the problem that is creating a barrier to learning, this being the acoustics in the given classroom.

A research study focussed on South African architects' considerations in classroom acoustics revealed that architects would want the following to be included in an ideal policy: financially considered regulations such as, cost-effective materials, regulations that can be easily implemented, materials for use in buildings that are economically viable, and sound transmission guidelines (Ryder, 2017). The design process that emerged from the current study could be generalised when assessing classrooms that need acoustic intervention. The recommended process is as follows:

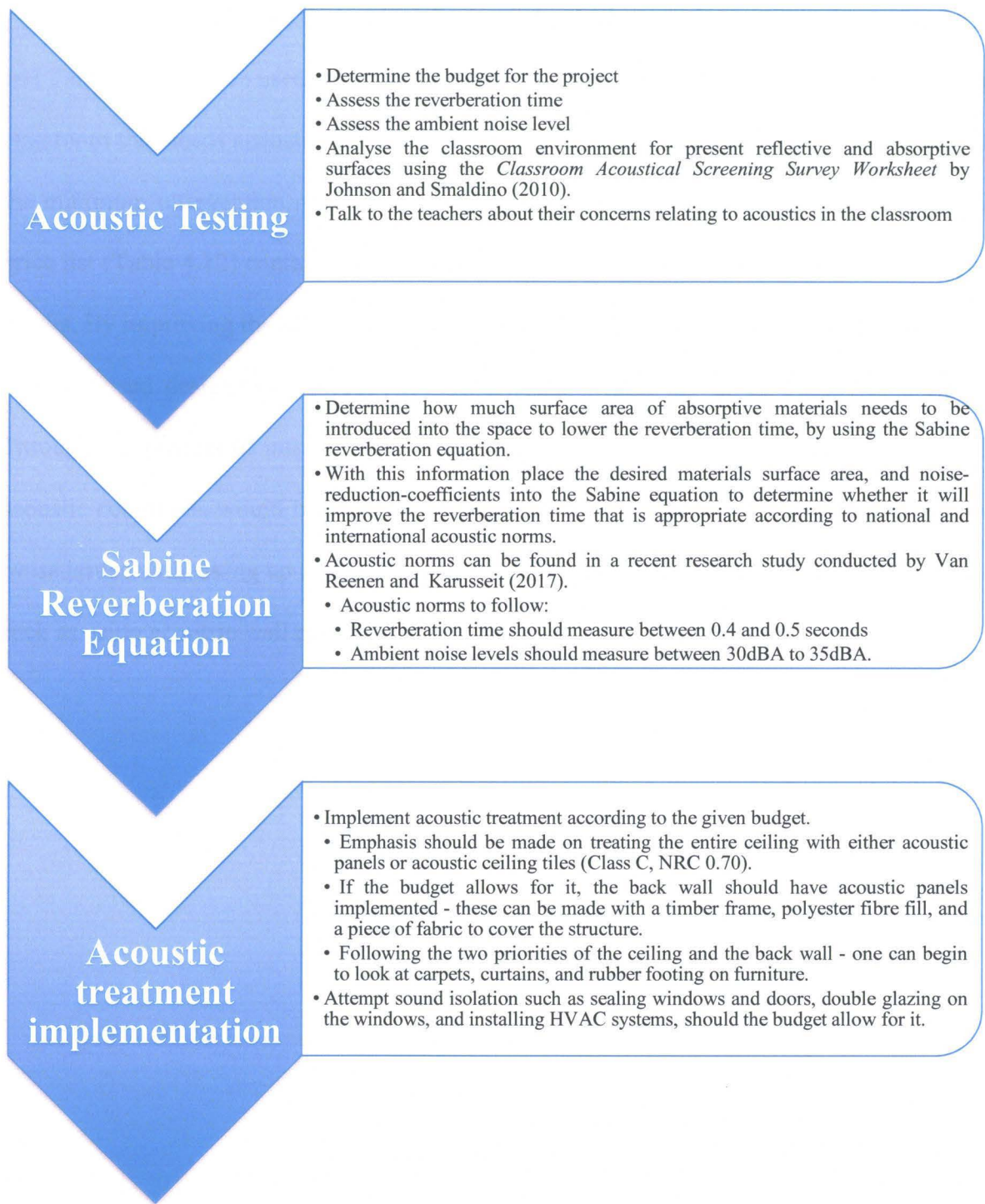


Figure 5.1. A process graph showing the steps that should be taken when attempting to acoustically treat a classroom on a budget as revealed from the current study.

This design process and material price list, which may change over time, (Figure 5.1 and Table 4.12) can be used to guide professionals who may be faced with a new or existing classroom that needs acoustic treatment on a budget. Using this method, one could determine the minimum intervention needed to establish appropriate acoustic conditions. The material price list (Table 4.12) contains the most effective and low-cost options based on this study's results. By improving the acoustic conditions with minimum intervention, one could create an individualised design that is cost-effective and fits within the given budget of a project. Through the process of interviewing the participants, the most ideal method to improve the acoustic conditions would be to treat the ceiling as this is a large surface area that does not cause issues with taking up space. The ceiling would not be vulnerable to damage or mis-use, such as using acoustic wall panels as pin-boards that diminishes efficacy.

Chapter 6: Conclusion

6.1. Summary of Results

The importance of research is to understand and gain information on policy, to gain deeper insight on an individual topic, and provide the opportunity for future research (Filho & Leal-Arcas, 2019). Through the completion of this study, the participants suggested low-cost designs to acoustically treat an example classroom. Nine out of the ten participants opted for acoustically treating the ceiling, as it was a large surface area to introduce absorption without taking up functional space. Nine out of ten participants opted for back wall acoustic treatment to reduce a slap-back echo and to create a functional space to pin-up relevant information. Carpets and curtains were suggested by many of the participants, however, should only be looked at after the main acoustic treatment has been done, for example, the ceiling or back wall. This is due to research proving that carpets and curtains do not have a major impact on acoustic conditions within a classroom. The general knowledge of South African acoustic norms was poor amongst the participants. However, the acoustic engineers did have more knowledge of the negative effects it can have on learners in the classroom. This could be because of their professional background. However, even the acoustic engineers were not entirely sure of the South African acoustic norms for schools.

A Wilcoxon matched paired-signed rank test was conducted to determine whether the post-acoustic treatment suggestions reverberation times were significantly better than the pre-acoustic treatment reverberation time. The test results indicated that the post-acoustic suggestions reverberation times were statistically significantly better than the pre-acoustic reverberation time. A Pearson's product-moment correlation coefficient was computed to assess the relationship between reverberation time (seconds) following the acoustic treatment suggestions and the estimated total price (ZAR) associated with each reverberation time. The

test showed an insignificant relationship between the price of materials and the post-acoustic treatment reverberation time. This may indicate that one does not need to spend a lot of money to achieve an appropriate reverberation time.

The lowest reverberation time was achieved by Participant 4, who chose to treat 100% of the ceiling as well as place acoustic panels on the back wall. The reverberation time came to 0.239 seconds at a price of R12 110.53. According to national and international standards, a reverberation time this low would enhance speech intelligibility but is not necessary. As the literature has stated before, one can still achieve 100% speech intelligibility at a reverberation time of 0.4 seconds. The cheapest acoustic treatment consideration was suggested by Participant 2, the price being, R8 494.00 and the reverberation time being, 0.441 seconds. According to international and national acoustic standards, this reverberation time falls adequately into the recommended acoustic norms for reverberation time. Participant 2 chose to treat 100% of the ceiling using a Class C ceiling tile, either OWAcooustic Futura or OWAcooustic Constellation, that both have an NRC rating of 0.70 and costs R145.00 per m². From a cost-effective and efficiency point of view, this seems to be the most ideal design to improve the acoustics of the example classroom.

In South Africa, there is limited and constrained access to resources, which could become challenging when comparing the need of acoustics in a classroom versus other basic needs, such as access to water and sanitation, which may be needed in the area. This research thus focussed on interrogating the most inexpensive acoustic improvement technique application to obtain the most amount of value in regard to acoustic treatments within existing classrooms. As mentioned previously this can be applied to Maslow's hierarchy of needs. Many of the previously disadvantaged schools are still running at the basic, physiological level of needs. Another important factor to consider is the ecology of where the learners are learning. There are many internal and external factors that influence the learner's

experience in the school environment. This means that certain necessities need to be addressed before acoustics can be thought of. This emphasises the reason as to why this study focussed on the least amount of costs to obtain the most amount of value in regard to acoustic treatments within existing classrooms. Acoustics should only be considered once the basic needs of the school environment and every learner is addressed. There is the need to ensure that the future children of South Africa are obtaining an education within an environment which supports them, not an environment that creates barriers to their access to education.

6.2. Limitations of the Study

Although this study may have found novel information in the South African context, there were limitations to the study. There was a small sample size of 10 participants, which could have been due to the inclusion criteria that needed a specific type of participant with specific experience and education levels. This enabled the researcher to obtain particular information that may have been more reliable due to the participants' qualifications. The reverberation times for the post-acoustic treatment suggestions were simulated and not conducted in real classrooms due to the feasibility of the study and time-frames. Despite the limitations of the study, information such as a protocol or guideline for acoustically treating an existing classroom was developed, as well as information was gained on the different materials that can be used in a classroom in the South African context. This makes the information more accessible to those who are involved in the acoustic treatment of existing classrooms. By interacting with professionals who may be involved in the acoustic improvement of a classroom, awareness was spread amongst the participants. The participants may be more aware of the impact of poor classroom acoustics on learners due to the information shared during the different phases of the research. This created a co-construction of knowledge between the researcher and the participants.

6.3. The Conclusion of This Study

Acoustics is an underestimated phenomenon with heightened importance for learners' learning environments and experiences. This study found that acoustically treating a classroom can be done in a cost-effective and efficient manner, but the design process needs to be specific and individualised. Acoustic treatment needs to be prioritised by treating the reverberation first and then, if the budget allows, the ambient noise levels. By using the Sabine equation, one can determine the exact amount of absorptive surface area that needs to be introduced into a space to achieve a reverberation time that is appropriate for a classroom. This allows the project manager to implement the bare minimum design to achieve acoustic adequacy at a cost-effective level. This study showed the importance of using an ecological framework that is imperative to the South African educational context. The South African educational context is complex in nature and has various elements that need to be delved into when debating on the internal and external factors that could be influencing a learner's experience in the classroom. This caused issues to emerge with prioritising intervention in classrooms which were adapted to the concept of Maslow's hierarchy of needs. Many South African schools seem to be at the basic needs level of the hierarchy, lacking access to nutrition, water, sanitation, and safety. Realistically, these needs should be considered prior to implementing acoustic and infrastructural improvements to classrooms. This study further emphasised that there is a great need for a change in policy at a government level to ensure that all South African classrooms have an environment that is conducive to learning and teaching. The negative implications of classroom acoustics are not necessarily known amongst professionals involved in the construction or management of classrooms; this needs to be solved through educational talks, discussions, and implementing change. There could be a significant impact and benefit of introducing a module on acoustics in the education of architects or courses for continuing professional development. Finally, a simple low-cost

acoustic improvement protocol was developed for professionals to use as a guideline when implementing acoustic improvements into existing classrooms.

6.4. Implications of the Study for Practice, Policy, and Further Research

The potential implications of this study were to gain insight into architects' and acoustic consultants' low-cost yet effective acoustic considerations when acoustically treating an existing classroom. All ten of the participants were unsure of the South African acoustic norms and standards for classrooms. Many of the participants expressed that this was due to the current acoustic norms and standards being very vague, or they were not sure where to find them, or if they even existed. This is a major issue that has been delved into before as it seems as though there is a problem with policy and norms in regard to classroom acoustics. There needs to be an upgrade in policy and norms in South Africa that are based on recent research, with efficient guidelines to assist professionals involved in classroom acoustics projects.

Through this study, the researcher took the information provided by the participants and developed a simple guideline that could assist those involved in classroom acoustics (Figure 5.1). This could assist professionals such as architects, acoustic consultants, or audiologists that are involved in this area. This could allow these professionals to develop a design that can provide the bare-minimum intervention to achieve an appropriate reverberation time. Maximising cost to benefit ratios in constrained contexts, such as in developing countries, it is vital due to the limited access of resources. By the acoustics project being cost-conscious, there is more budget for other important projects, for example, improving resources in a school. As mentioned in the literature review, there is an abundance of research and information on the effects of poor classroom acoustics and noise in the classroom on a learner's academic performance. Literature also shows that poor classroom

acoustics may create a barrier to learning that both typically developing learners and learners with learning difficulties are majorly influenced by. Solutions need to be discussed and found, without which we are allowing millions of classrooms both nationally and internationally to be acoustically inadequate with increased noise levels, knowing the negative effects it may be having on the learners. This research is the start of a discussion on the solution to this well-known and growing problem. By speaking to the professionals who are involved in the development of educational facilities, first-hand information was obtained which allowed for the development of an acoustic protocol which may provide clear guidelines that could be followed with ease. There are future research opportunities which involve incorporating the participants' acoustic treatment considerations into existing classrooms and measuring how reverberation times and noise levels improve while keeping to a limited budget.

As mentioned at the beginning of this dissertation, Nelson Mandela once said, "Education is the most powerful weapon which you can use to change the world" (Soudien, 2005, p.134). Madiba placed emphasis on the importance of educating the youth to empower them with knowledge and skills to make a positive change to South Africa. This study found a method to ensure that classrooms in South Africa can be improved in a low-cost way to ensure that every individual, in every type of classroom, has the right to an accessible education. There is the need to ensure that the future children of South Africa are obtaining an education within an environment which supports them, not an environment that creates barriers to their learning and obstructs their educational process. The professionals involved in the development of classrooms have a responsibility to limit barriers to learning in the classroom. By working as a team, there is the opportunity to make positive changes in South Africa's learning environments and truly making education more accessible for all.

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Appendices

Appendix A



Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Kassuto

CLEARANCE CERTIFICATE

PROTOCOL NUMBER: H18/04/11

PROJECT TITLE

Architects' and acoustic consultants' low-cost considerations for improving classroom acoustics in the South African Context

INVESTIGATOR(S)

Miss C Kassuto

SCHOOL/DEPARTMENT

Human and Community Development/

DATE CONSIDERED

20 April 2018

DECISION OF THE COMMITTEE

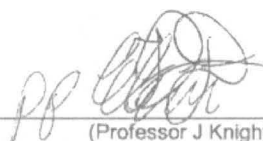
Approved

EXPIRY DATE

10 June 2021

DATE 11 June 2018

CHAIRPERSON

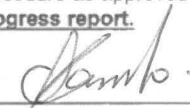

(Professor J Knight)

cc: Supervisor : Dr V de Andrade and Mrs L Petrocchi-Bartal

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to completion of a yearly progress report.


Signature

20 / 4 / 2018
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix B



SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)



Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Information Sheet and Consent Form

Pilot Study

To whom it may concern,

My name is Chantal Kassuto and I am a master's student in audiology at the University of the Witwatersrand in Johannesburg. As part of my research project I am investigating: Architects' and Acoustic Consultants' Low-Cost Considerations for Improving Classroom Acoustics in the South African context. The aim of this research project is to explore architects' and acoustic consultants' considerations for low-cost yet effective ways to acoustically treat an existing classroom.

There is an abundance of research highlighting the effects of poor classroom acoustics on the academic performance on learners of all learning capabilities in the classroom. It is evident that acoustical considerations are vital in the reduction of environmental barriers to learning in the classroom. It is also evident that many classrooms within South Africa do not have adequate acoustic properties which should be in line with the South African standards and regulations in regard to reverberation times and ambient noise levels; this could be due to limited and constrained resources. The purpose of this research is not only being conducted to discover a **low-cost yet effective way to acoustically treat an existing classroom** but also to create awareness of the importance of having an acoustically adequate classroom which

allows all learners of all learning capabilities to have ease of access to education. This further highlights the need for an acoustically friendly classroom design which is easy to follow and guides the professionals involved in building classrooms to apply correct measures and methods to reach the appropriate levels of reverberation times and ambient noise levels within the learning environment. The focus will be on **reducing reverberation times and ambient noise levels, while improving the Speech Transmission Index (STI) for speech intelligibility, with the least cost and most value in the South African context.** I would like to include architect's and acoustic consultant's as my participants due to their involvement in the design and implementation of acoustic treatments in classrooms.

For the purpose of this project I need to conduct a pilot study to ensure reliability and validity of my study and qualitative data collection. The main aim of a pilot study is to attempt the research approach before the main conduction of the data collection in order to identify any problems that may arise and affect the quality and validity of the results. This allows the researcher to make any necessary changes to each question based on the results of the questions asked or methods conducted. This could add to the effectiveness and efficiency of the study.

As part of this project I would like to invite you to take part of the following research phases:

Phase one: The participant will be given written information and visual representation regarding an example of a classroom, for example, the physical characteristics. This information provides an 'image' of an example of a classroom which requires acoustic treatments. This will allow the participant to have appropriate expectations of what the research processes will contain. By allowing the participant to read over what the research contains in advance, it will allow them to understand what is needed from them. The participant will be requested to think about or, if they wish, prepare the following prior to the

interview in phase two: Pricing of the chosen material for acoustically treating the existing classroom, the materials absorption coefficient/ noise reduction coefficient (NRC) (if possible), method of implementing the acoustic treatments, layout of the classroom, and suggestions for further management to acoustically treat the existing classroom.

Phase two: The researcher will provide a 3D representation of the classroom and cross-sections of the walls in the classroom on paper. The participant will be requested to roughly draw out their prepared considerations to acoustically treat the existing classroom according to the table of information of the classroom scenario. While the participant is drawing, the participants will be requested to label and elaborate on the considerations and choices made during the drawing procedure. The researcher will participate in this phase in a conversational manner which will be audio recorded for analysis purposes. Following the drawing procedure the participant will undergo a single and individual semi-structured interview, questions will be formed and based on the drawing and the participants' experience with classrooms. With your permission, I would also like to **audio record** the interview using a digital device. The audio recordings will be downloaded onto a password protected computer which only the researcher has access to. This should take around 60 minutes. The drawings will be archived in a locked cabinet that only the researcher and research supervisor have access to. Following the interview process, I will send (email) you the transcription of your interview to read over to ensure that you are comfortable with everything that was documented in the interview, prior to analysis of the results. There may be some related questions for clarification attached to the transcription for you to please answer to your best ability.

You will not receive any direct benefits from participating in this study, and there are no disadvantages nor penalties for not participating. You may withdraw at any time or not answer any question if you do not want to. Your identity will only be known to me and my research supervisor. The interview will be completely confidential and anonymous as I will

not be asking for your name or any identifying information on record, and the information you give to me will be held securely within a password protected computer that only the researcher has access to and not disclosed to anyone else. If the pilot study is presented in the research report, I will be using a pseudonym (false name) to represent your drawings and participation in my final research report.

If you have any questions prior to, during, or after the research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available to all participants. If you wish to receive a summary of this report, I will be happy to send it to you upon request.

Thank you for taking the time to read this information sheet.

Yours sincerely,

Miss Chantal Kassuto

Research Supervisors:	Dr Victor de Andrade victor.deandrade@wits.ac.za Mrs Luisa Petrocchi-Bartal luisa.petrocchi-bartal@wits.ac.za
Researcher:	Miss Chantal Kassuto
Researchers email:	chantal.kassuto@gmail.com
Researchers contact number:	079 4878 487

If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical).

HREC (non-medical) Administer: Name	Shaun Schoeman
Work Tel:	011 717 1408
Email:	hrec-medical.researchoffice@wits.ac.za/ Shaun.Schoeman@wits.ac.za

Consent Form

(Pilot Study)

Title of Project: Architects’ and Acoustic Consultants’ Low-Cost Considerations for Improving Classroom Acoustics in the South African context

Name of researcher: Ms Chantal J. Kassuto

I agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

Please circle:

I agree that my participation will remain anonymous.	YES	NO
--	-----	----

I agree that the researcher may use anonymous quotes in her research report.	YES	NO
--	-----	----

I agree that the interview will be audio recorded for analysis purposes.	YES	NO
---	-----	----

I am aware that the data collected will be stored in a password protected computer and the physical data will be archived in a lock cabinet which only the researcher has access to.	YES	NO
--	-----	----

I agree that the researcher can use my drawings in the research report, and future research purposes	YES	NO
--	-----	----

(anonymously).

I agree that the information I provide may be used

YESNO

anonymously by other researchers following this study.

I agree that I am participating in a pilot study, and

YESNO

therefore my data may not be used in the main data analysis

of the study.

..... (Signature)

..... (Name of participant)

..... (Date)

Appendix C



SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)



Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Participant Information Sheet

(General)

Dear Sir/Madam,

My name is Chantal Kassuto and I am a masters student in audiology at the University of the Witwatersrand in Johannesburg. As part of my research project I am investigating: Architects' and Acoustic Consultants' Low-Cost Considerations for Improving Classroom Acoustics in the South African context. The aim of this research project is to explore architects' and acoustic consultants' considerations for low-cost yet effective ways to acoustically treat an existing classroom.

There is an abundance of research highlighting the effects of poor classroom acoustics on the academic performance on learners of all learning capabilities in the classroom. It is evident that acoustical considerations are vital in the reduction of environmental barriers to learning in the classroom. It is also evident that many classrooms within South Africa do not have adequate acoustic properties which should be in line with the South African standards and regulations in regard to reverberation times and ambient noise levels; this could be due to limited and constrained resources. The purpose of this research is not only being conducted to discover a **low-cost yet effective way to acoustically treat an existing classroom** but also to create awareness of the importance of having an acoustically adequate classroom which allows all learners of all learning capabilities to have ease of access to education. This further

highlights the need for an acoustically friendly classroom design which is easy to follow and guides the professionals involved in building classrooms to apply correct measures and methods to reach the appropriate levels of reverberation times and ambient noise levels within the learning environment. The focus will be on **reducing reverberation times and ambient noise levels, while improving the Speech Transmission Index (STI) for speech intelligibility, with the least cost and most value in the South African context.** I would like to include architect's and acoustic consultant's as my participants due to their involvement in the design and implementation of acoustic treatments in classrooms.

As part of this project I would like to invite you to take part in the following research phases:

Phase one: The participant will be given written information and visual representation regarding an example of a classroom, for example, the physical characteristics. This information provides an 'image' of an example of a classroom which requires acoustic treatments. This will allow the participant to have appropriate expectations of what the research processes will request. By allowing the participant to read over what the research contains in advance, it will allow them to understand what is needed from them. The participant will be requested to think about or, if they wish, prepare the following prior to the interview in phase two: Pricing of the chosen material for acoustically treating the existing classroom, the materials absorption coefficient/ noise reduction coefficient (NRC) (if possible), method of implementing the acoustic treatments, layout of the classroom, and suggestions for further management to acoustically treat the existing classroom.

Phase two: I will provide a 3D representation of the classroom and cross-sections of the walls in the classroom on paper. The participant will be requested to roughly draw out your considerations to acoustically treat the existing classroom according to the table of information of the classroom scenario. While the participant is drawing, the participant will

be requested to label and elaborate on the considerations and choices made during the drawing procedure which will be audio recorded for analysis purposes. Following the drawing procedure the participant will undergo a single and individual semi-structured interview, questions will be formed and based on the drawing and the participants experience with classrooms. With your permission, I would also like to audio record the interview using a digital device. The audio recordings will be downloaded onto a password protected computer which only the researcher has access to. This should take around 60 minutes. The drawings will be archived in a locked cabinet that only the researcher and the research supervisors have access to. Phase two will be conducted at a convenient time and place for the participant, this will be in line with the ethical standards to ensure the research is conducted within an ethical manner. Following the interview process, I will send (email) you the transcription of your interview to read over to ensure that you are comfortable with everything that was documented in the interview, prior to analysis of the results. There may be some related questions for clarification attached to the transcription for you to please answer to your best ability.

Phase three: This phase does not need the participation of any participants. Results obtained from phase two be placed in the Sabine reverberation equation for reverberation times pre- and post-acoustic treatments.

You will not receive any direct benefits from participating in this study, and there are no disadvantages nor penalties for not participating. You may withdraw at any time or not answer any question if you do not want to. Your identity will only be known to me and my research supervisor. The interview will be completely confidential and anonymous as I will not be asking for your name or any identifying information on record, and the information

you give to me will be held securely within a password protected computer that only I have access to and will not be disclosed to anyone else. I will be using a pseudonym (false name) to represent your drawings and participation in my final research report. If you participate in the focus-group interview, confidentiality and anonymity cannot be guaranteed, however all participants will be required to sign a non-disclosure agreement and you will not be required to identify yourself nor which firm you work for during the focus-group.

If you have any questions prior to, during, or after the research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available to all participants. If you wish to receive a summary of this report, I will be happy to send it to you upon request.

Thank you for taking the time to read this information sheet.

Yours sincerely,

Miss Chantal Kassuto

Research Supervisors:	Dr Victor de Andrade victor.deandrade@wits.ac.za Mrs Luisa Petrocchi-Bartal luisa.petrocchi-bartal@wits.ac.za
Researcher:	Miss Chantal Kassuto
Researchers email:	chantal.kassuto@gmail.com
Researchers contact number:	079 4878 487

If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical).

HREC (non-medical) Administer: Name	Shaun Schoeman
Work Tel:	011 717 1408
Email:	hrec-medical.researchoffice@wits.ac.za/ Shaun.Schoeman@wits.ac.za

Appendix D



SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)



Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Participant Information Sheet

Phase One and Two

Dear Sir/Madam,

My name is Chantal Kassuto and I am a masters student in audiology at the University of the Witwatersrand in Johannesburg. As part of my research project I am investigating: Architects' and Acoustic Consultants' Low-Cost Considerations for Improving Classroom Acoustics in the South African context. The aim of this research project is to explore architects' and acoustic consultants' considerations for low-cost yet effective ways to acoustically treat an existing classroom.

As part of this project I would like to invite you to take part in three research phases. This information sheet will be providing information regarding **PHASE ONE** and **PHASE TWO**:

Phase one: The participant will be given a table of written information and illustrations that represent the example classroom. This information will allow the participant to visualise an 'image' of the example classroom which requires acoustic treatments. Phase one is the preparation phase, the participants can think about or prepare, if they wish, low-cost and effective materials to acoustically treat the classroom. By providing the participant with this

information beforehand, expectations can be managed appropriately for what the research process is going to contain.

The participant will be encouraged to read over the following information prior to phase two:

- Pricing of the chosen material for acoustically treating the existing classroom,
- The materials absorption coefficient/ noise reduction coefficient (NRC) (if possible),
- Method of implementing the acoustic treatments, layout of the classroom,
- And suggestions for further management to acoustically treat the existing classroom.

I will be in contact with you to make an appointment for your individual interview which is the start to phase two.

Phase two: Phase two will be conducted at a convenient time and place for the participant, this will be in line with the ethical standards to ensure the research is conducted within an ethical manner.

The researcher will provide a 3D representation of the classroom and cross-sections of the walls in the classroom on paper. The participant will be requested to roughly draw out their considerations to acoustically treat the existing classroom according to the table of information of the classroom scenario. While the participant is drawing, the participants will be requested to label and elaborate on the considerations and choices made during the drawing procedure which will be audio recorded for analysis purposes. Please do not write any identifying information on your drawings. The researcher will write which number participant you are on the drawing so that it is identifiable by the researcher, yet anonymous to future readers. The drawings will be used in the research report, however your name will be kept anonymous. The drawings will be archived in a locked cabinet that only I, the researcher, and research supervisor have access to.

Following the drawing procedure the participant will undergo a single and individual semi-structured interview, questions will be formed and based on the drawing and the participants' experience with classrooms. With your permission, I would also like to audio record the interview using a digital device. The audio recordings will be downloaded onto a password protected computer which only the researcher has access to. This should take around 60 minutes. Following the interview process, I will send (email) you the transcription of your interview to read over to ensure that you are comfortable with everything that was documented in the interview, prior to analysis of the results. There may be some related questions for clarification attached to the transcription for you to please answer to your best ability.

Please read and sign the consent form, attached, which refers to both phases one and two for informed consent purposes.

You will not receive any direct benefits from participating in this study, and there are no disadvantages nor penalties for not participating. You may withdraw at any time or not answer any question if you do not want to. Your identity will only be known to me and my research supervisor. The interview will be completely confidential and anonymous as I will not be asking for your name or any identifying information on record, and the information you give to me will be held securely within a password protected computer that only the researcher has access to and not disclosed to anyone else. I will be using a pseudonym (false name) to represent your drawings and participation in my final research report.

If you have any questions prior to, during, or after the research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available

to all participants. If you wish to receive a summary of this report, I will be happy to send it to you upon request. Should you decide to participate, I thank you for your participation and contribution to the field of research.

Thank you for taking the time to read this information sheet.

Yours sincerely,

Miss Chantal Kassuto

Research Supervisors:	Dr Victor de Andrade victor.deandrade@wits.ac.za Mrs Luisa Petrocchi-Bartal luisa.petrocchi-bartal@wits.ac.za
Researcher:	Miss Chantal Kassuto
Researchers email:	chantal.kassuto@gmail.com
Researchers contact number:	079 4878 487

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HREC (non-medical) Administer: Name	Shaun Schoeman
Work Tel:	011 717 1408
Email:	hrec-medical.researchoffice@wits.ac.za/ Shaun.Schoeman@wits.ac.za

Appendix E



SPEECH PATHOLOGY & AUDIOLOGY

THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)



Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Consent Form

(Phases one and two)

Title of Project: Architects’ and Acoustic Consultants’ Low-Cost Considerations for Improving Classroom Acoustics in the South African context

Name of researcher: Ms Chantal J. Kassuto

I agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

Please circle:

I agree that my participation will remain anonymous.

YESNO

I agree that the researcher may use anonymous quotes in her research report.

YESNO

I agree that the interview will be **audio recorded** for analysis purposes.

YESNO

I am aware that the data collected will be stored in a

YESNO

password protected computer which only the researcher

has access to.

I agree that the researcher can use my drawings in the

YESNO

research report, and future research purposes

(anonymously).

I understand that the drawings will be archived in a locked

YESNO

cabinet that only the researcher and research supervisor

have access to.

I agree that the information I provide may be used

YESNO

anonymously by other researchers following this study

I agree that the information I provide during the interview

YESNO

may be used anonymously in an online software named

i-Simpa for further analysis of the suggested materials

acoustic effectiveness.

..... (Signature)

..... (Name of participant)

..... (Date)

Appendix F



SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)



Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Cover Letter for Architectural and Acoustic Consultant Firms

To whom it may concern,

The purpose of this letter is to provide you with information on my research study. I, Chantal Kassuto, am currently enrolled in a master's program MA Audiology at the University of the Witwatersrand in Johannesburg. I am conducting research on the following topic: Architects' and Acoustic Consultants' Low-Cost Considerations for Improving Classroom Acoustics in the South African context.

There is an abundance of research highlighting the effects of poor classroom acoustics on the academic performance on learners of all learning capabilities in the classroom. It is evident that acoustical considerations are vital in the reduction of environmental barriers to learning in the classroom. It is also evident that many classrooms within South Africa do not have adequate acoustic properties which should be in line with the South African standards and regulations in regard to reverberation times and ambient noise levels; this could be due to limited and constrained resources. The purpose of this research is not only being conducted to discover a **low-cost yet effective way to acoustically treat an existing classroom** but also to create awareness of the importance of having an acoustically adequate classroom which allows all learners of all learning capabilities to have ease of access to education. This further highlights the need for an acoustically friendly classroom design which is easy to follow and guides the professionals involved in building classrooms to apply correct measures and

methods to reach the appropriate levels of reverberation times and ambient noise levels within the learning environment. The focus will be on **reducing reverberation times and ambient noise levels, while improving the Speech Transmission Index (STI) for speech intelligibility, with the least cost and most value in the South African context.** I would like to include architects and acoustic consultants as my participants due to their involvement in the design and implementation of acoustic treatments in classrooms.

My inclusion criteria for participants includes the following:

<i>Acoustic Consultants.</i> • Qualified acoustic consultant • Acoustic consultants who have at least one year practical experience. • Acoustic consultants who have/had exposure and experience in the design and construction in an educational facility will be a bonus, however due to their speciality any experience in acoustical treatment will suffice for this research study.	<i>Architects.</i> • Qualified architects, as per the requirement set out by SAIA. • Architects who have at least one year practical experience. • Architects who have/had exposure and experience in the design and construction in an educational facility.
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Please could you forward this on to any possible participants within the firm/company or other colleagues who would be interested. Participants who are interested in participating in the research study can contact me on the details provided below. Further information regarding the research study will be provided to the participants interested in participating with an information sheet (please find attached to the email). All information obtained during the study will be kept highly confidential and anonymous, and all results obtained will be shared with all participants to share with colleagues and others, as desired.

Thank you for reading the above letter. If you have any queries, concerns, or questions, please do not hesitate to contact me on: **chantal.kassuto@gmail.com** or **079 4878 487.**

Kind regards,

Miss Chantal J. Kassuto

Audiologist and Speech-Language Pathologist

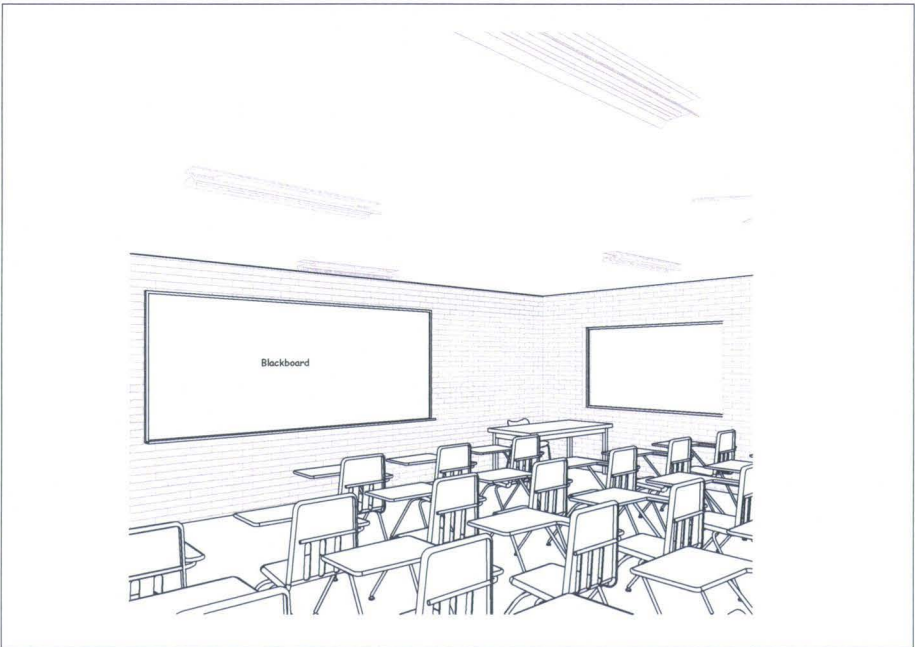
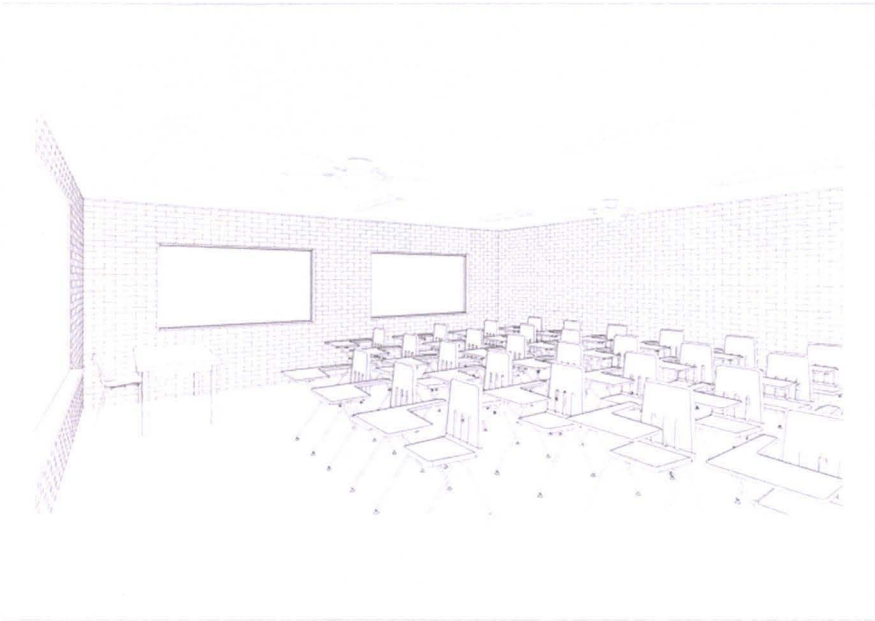
Research Supervisors:	Dr Victor de Andrade victor.deandrade@wits.ac.za Mrs Luisa Petrocchi-Bartal luisa.petrocchi-bartal@wits.ac.za
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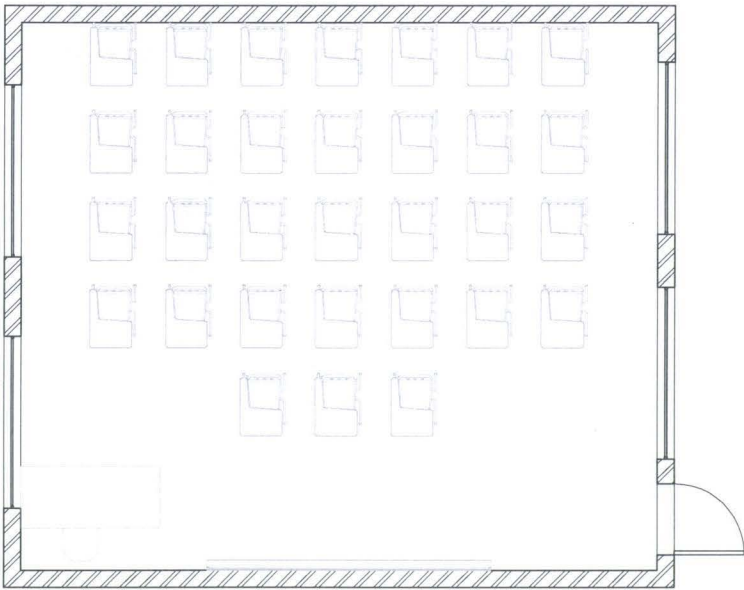
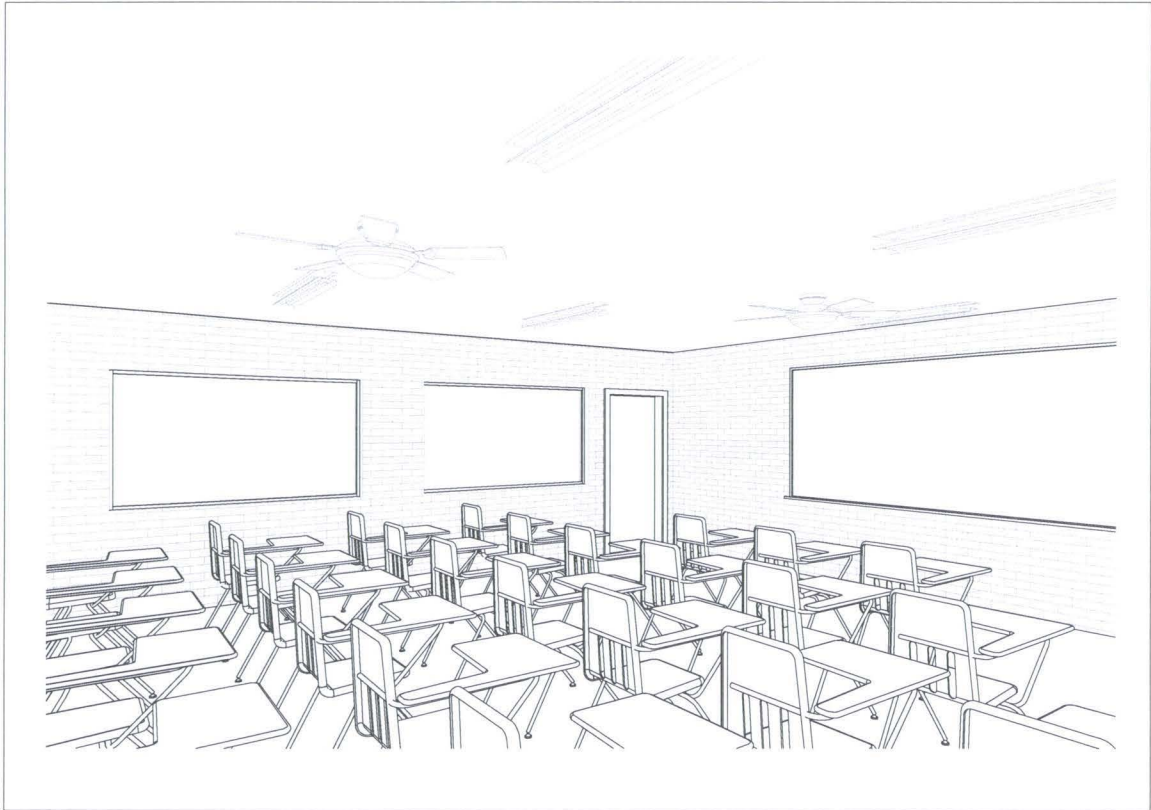
Appendix G

SPEECH PATHOLOGY & AUDIOLOGY
THE SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT (SHCD)

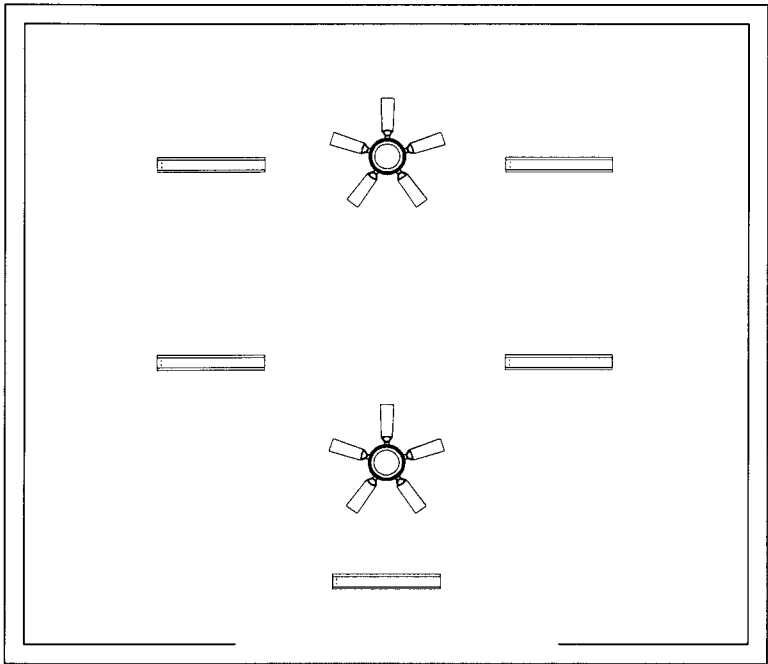
Private Bag 3, Wits, 2050 • Tel: 011 717 4577 • Fax: 011 717 4572 • E-mail: sppa.SHCD@wits.ac.za

Perspective Images of the Example Classroom



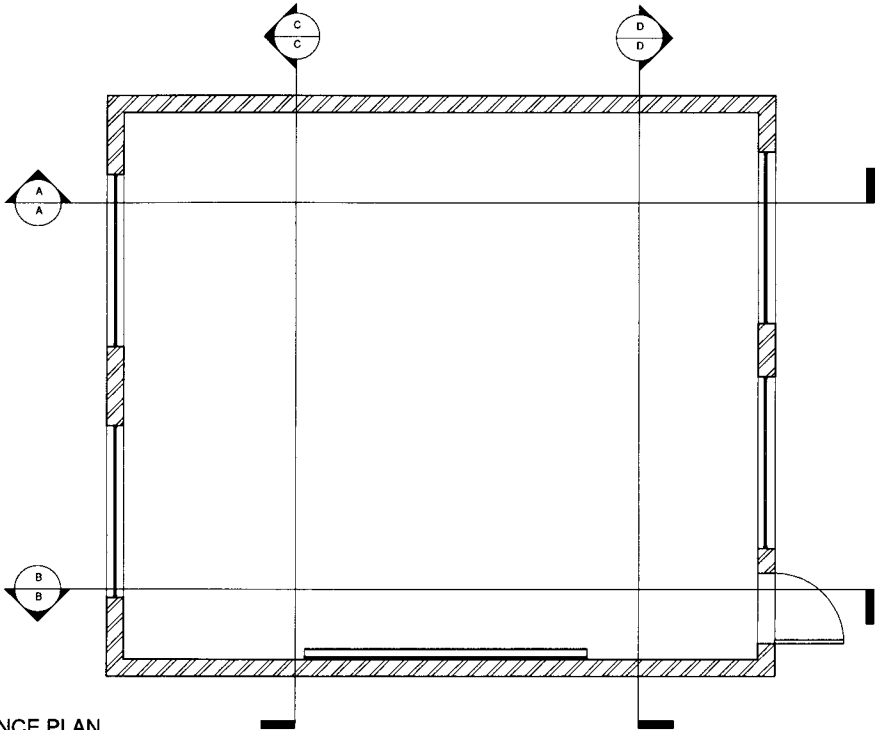


EXAMPLE CLASSROOM FURNITURE LAYOUT
SCALE 1:50

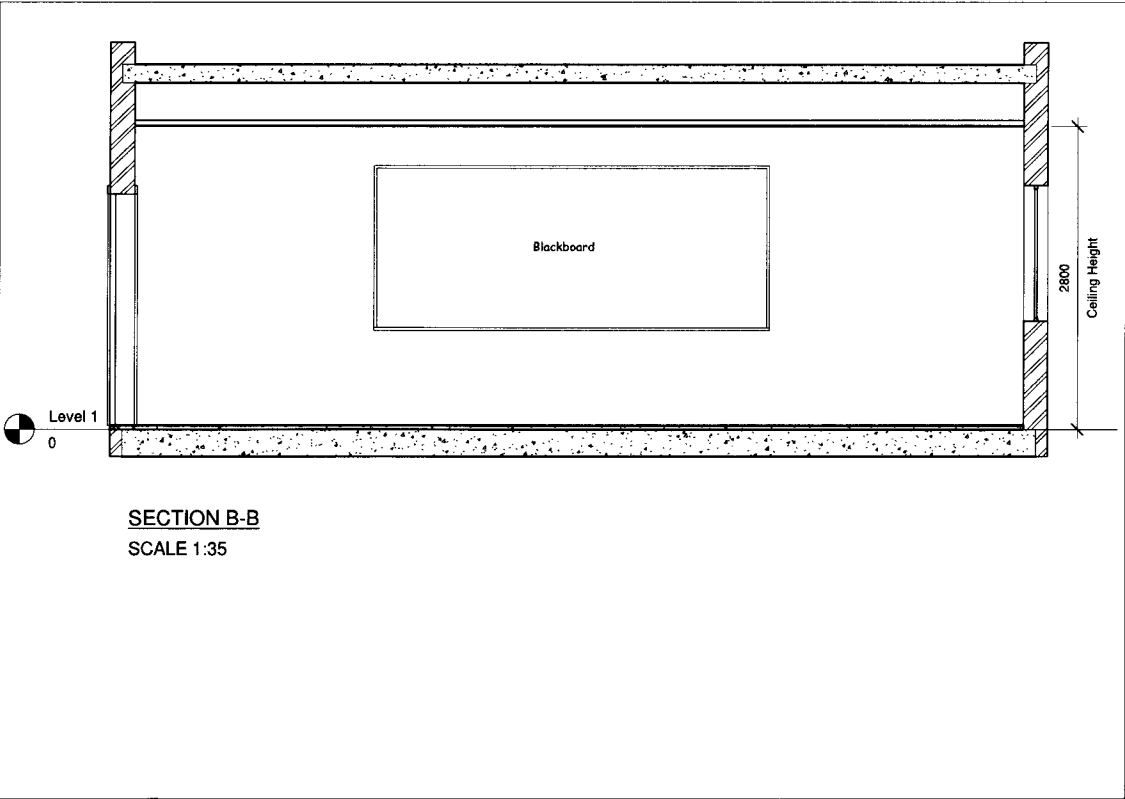
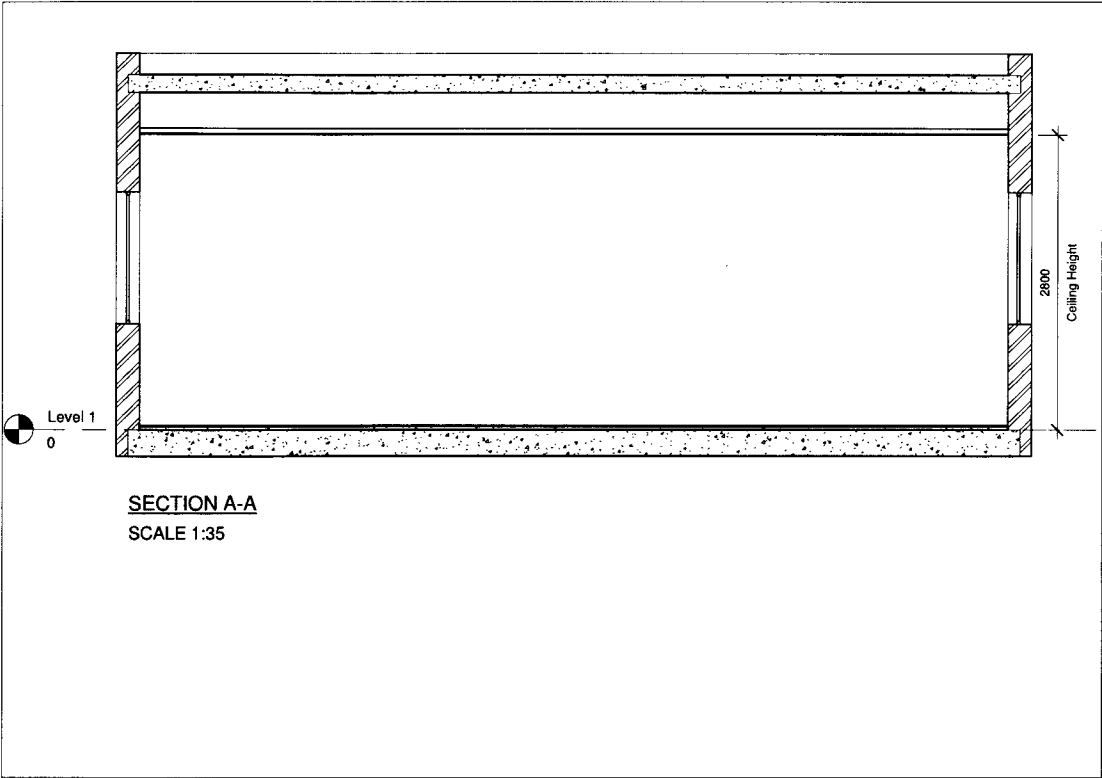


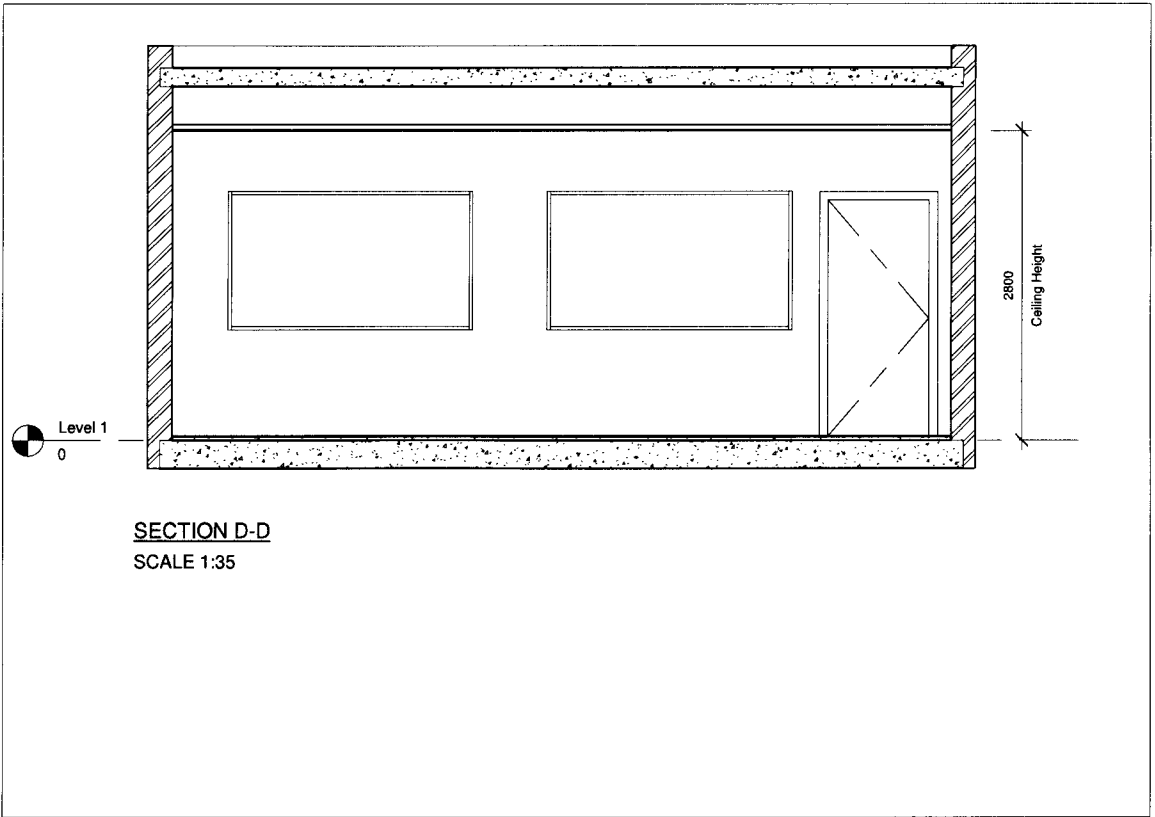
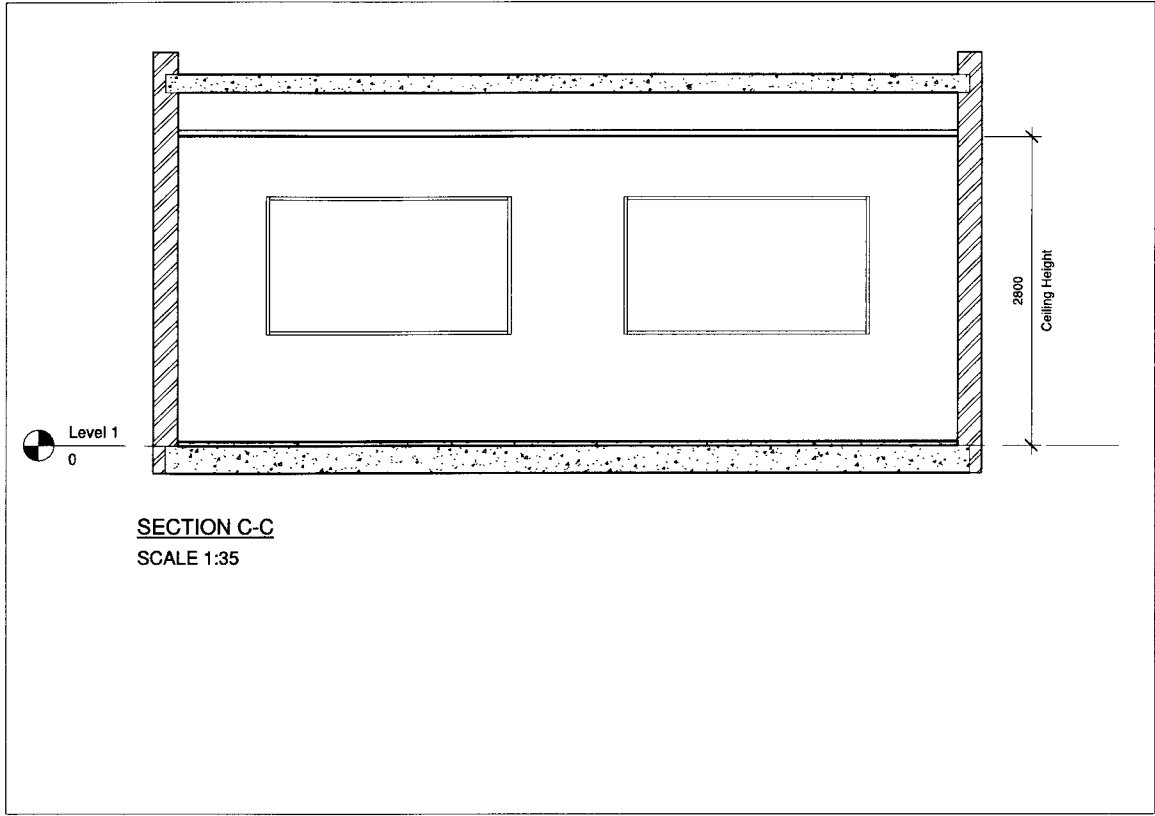
EXAMPLE CLASSROOM REFLECTED CEILING PLAN
SCALE 1:50

Cross-Section of the Classroom Image for Drawing (Phase Two)



REFERENCE PLAN
SCALE 1:50





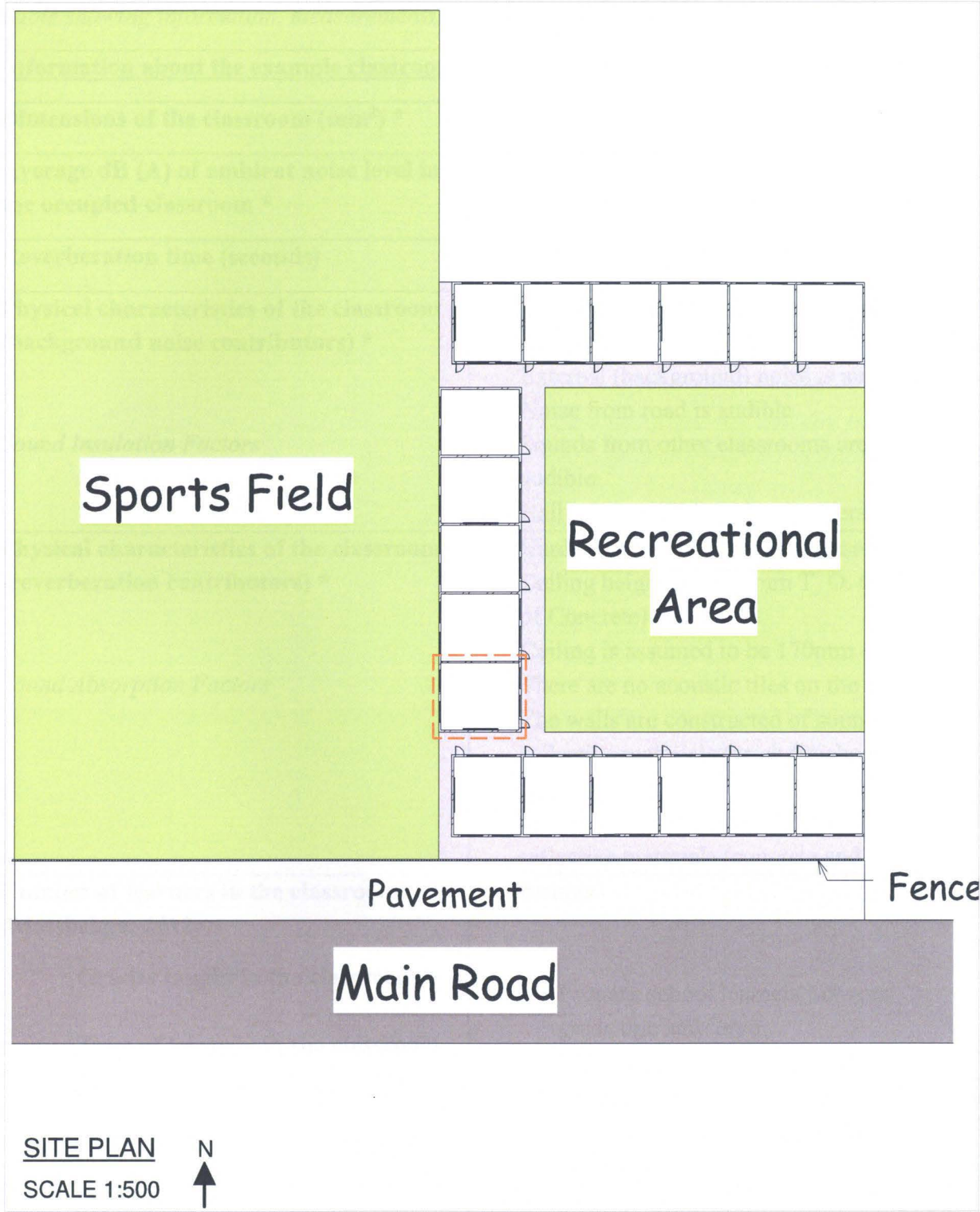


Table showing information, measurements, and details of the example classroom.

<u>Information about the example classroom</u>	<u>Measurements and details of classroom</u>
Dimensions of the classroom (mm²) *	8220 x 7060
Average dB (A) of ambient noise level in the occupied classroom *	70,8 dB (A)
Reverberation time (seconds)	1,4 seconds
Physical characteristics of the classroom (background noise contributors) * <i>Sound Insulation Factors</i>	- The heating and ventilation systems are audible - External (background) noise is audible - Noise from road is audible - Sounds from other classrooms are audible - Hallway is audible (other learners)
Physical characteristics of the classroom (reverberation contributors) * <i>Sound Absorption Factors</i>	- Hard surfaces surround the classroom - Ceiling height is 2800 mm T. O. C. (Top of Concrete) - Ceiling is assumed to be 170mm deep - There are no acoustic tiles on the ceiling - The walls are constructed of sound reflective materials (brick finished with plaster and paint) - Floors are constructed of sound reflective materials (concrete and tiles)
Number of learners in the classroom (Motshekga, 2012) - Grades taught in the classroom * - Type of learners in the classroom *	31 learners - Primary school learners between grade one and three. - Mainstream classroom, meaning learners that may have learning difficulties are learning in this classroom.
Desks and chairs *	Each child has their own desk and chair (31) made out of plastic and metal material.
Windows and doors *	There are two big windows across two walls, two facing towards the sports field and two facing towards the corridor. There are no blinds or curtains. - Aluminium framed windows

	- Glass is 2mm thick One wooden door that is used for entering and exiting.
Location of the classroom	Positioned near a busy road (15m) and a field (5m) where learners play sport during learning time. There is also a recreational area located outside of the classroom door. The classroom is located in a row of classrooms and is near the corridor which leads to the field and to more classrooms (please refer to the site plan in Appendix F for an illustration of the position, the classroom is marked with an ‘X’). The classroom is located in a two story building on the ground floor.

*Measurements taken from research conducted by Kassuto (2016) with use of the adapted *Classroom Acoustical Screening Survey Worksheet* by Johnson and Smaldino (2010).

Appendix H

Table 2

Acoustic treatment to improve reverberation time.

Dominant Themes:	Excerpts from the interviews:
Prioritise acoustic treatment for reverberation time	Participant 4: Line 28-29 “But to treat the space and for internal acoustic quality, it's not a huge, relative to the rest it's the least expensive and easiest to do here.” Line 82-86“Well in the case, it is easier I think, to deal with reverb (<i>reverberation</i>) time... Mainly because ambient noise level reduction from one space to another is based on the structure itself. And to fix this window, wall, or door is going to be more costly than to put things on the wall. “ Line 197-199 “...we can talk about teaching methods, and the syllabus and etc. etc. but you know if you don't have the space to do teaching um... you know, it's just not going to work.” Participant 5: Line 53-56 “So it's important to know where this (<i>referring to the frequency spectrum where speech is found</i>) is based because when you design a space you obviously looking at the reverberation target that you want to achieve. The lower the frequency goes the longer the reverb time will be because of more energy and so forth.” Line 130-133 “...in terms of reverberation, there is a minimum area that you can introduce into a space that will actually make a usable or functional difference. Like putting two or three panels into the space probably won't do much but there's a certain limit for you to get to that point where it can actually make a difference.” Line 143-146 “So... it's a cost balancing thing um... ja so for each classroom, it can be calculated (<i>with the Sabine equation</i>), what do we need to do to make this work and typically it would be a full ceiling and some wall panels of 0.7 efficiency, that's around the industry standard. We don't specify anything less than 0.7. “ Participant 7:

	Line 23-27 "...so I'd start off with that um... the ceiling is one of the cheapest ways to do it, it's still expensive but the cheapest way to introduce absorption. Um... so the furniture layout what do we have... in terms of the ceiling layout, one of the cheapest ways to do it is to put a suspended ceiling in with acoustic tiles. " Line 130-135 "The only other way to do it is going back to your reverberation in taking down your reverberation to... generally... it's less than 0.4 seconds especially when there's learning difficulties, we would be looking at a value of 0.4 seconds RT. Um... that will make the space a lot quieter. People shout less, and you'll see that by just dealing with reverberation time it will bring down this ambient noise level significantly." Line 138-140 "I would say, first things first focus on reverberation, bring that down and then you'll find that everyone... the kids will be quieter the kids will be quieter and it will just be a genuinely quieter space..." Participant 10 Line 29-31 "...rather targeting the act that the acoustic experience inside the classroom is a more approved one is the first step for me if you're looking at lower cost interventions." Line 285-288 "um... shifting the acoustic environment internally, so improving room acoustics or acoustic absorption rather than improving sound insulation um... and using culture/behaviour programming etc.... to lower the disruption rather than promote..."
Acoustic treatment of the ceiling	Participant 1: Line 40-42 "Um... low-cost solution so a good starting point for the ceiling would be to have what we call 'clouds' absorption panels that hang from the ceiling, which are suspended from the ceiling." Line 48 "Obviously the more absorption panels you add the lower the reverb time will become." Line 57-60 "...um... one type of product would be more like a solid piece of absorption material which looks almost like a ceiling tile but they come in different shapes and sizes um... some are round, triangular." Line 63-66 "...the other side would be to use high-density absorption material, there are two different materials – the one is mineral wool and the other one would be high-density polyester. The

mineral wool, if you looking at classrooms and children and health and safety and all that kind of stuff.”

Line 178-179 “...especially above the children.”

Line 181-187 “Okay or where the learners/seating is placed because that is obviously when the children talk the sound actually goes up, bounces from the ceiling and um... and then goes to your... however obviously sound goes in all directions so it bounces off the ceiling um... so if your clouds are above the uh... the chairs and the seat and obviously you're targeting your first reflections ja.. The sound going up can go up to the ceiling and bouncing and going down um... or uh ja and being spread throughout the classroom.”

Participant 2:

Line 121-122 “...we cover 100% with the ceiling tile is a number, we almost within this ballpark (*of the ideal reverberation time*).”

Line 129-130 “...if we do this (*cover 100% of the ceiling*) the cheapest tile on the market we can get to this (*the ideal reverberation time*).”

Line 134-135 “So if we cover the ceiling and tile it with 0.7 (*NRC value*) material we will get to about this number (*0.8 reverb time*).”

Line 232-235 “So typically in a standard classroom height, reflection in this area (*above the teacher*) is actually beneficial okay so this zone here quite often can be useful to reflect sound because it's being used for this purpose okay. Then instead of putting 100% of ceiling, I'm leaving this zone empty here (*front 1/3 of ceiling*) and then here I'm also getting benefit of not doing this.”

Line 293-297 “If we apply this material with glass wool on the wall you're getting so little option that's actually why, why one prioritize putting absorption on the ceiling and then again because in many classrooms we could not afford to do this yet because we actually do want pin board and notice board space plus it will end up going for this. Then it will become, going back to 100% ceiling coverage.”

Line 349-350 “Your standard cheapest acoustic treatment is fibreglass, typically R100-R150/square meter or polyester fibre.”

Line 382-386 “So, when you look at 0.65 tiles here this is tested under 200ml suspension. So if you put this tile on the wall it actually becomes more like 30% efficient than 65% efficient... So this again

why we put in more on the ceiling than on the wall.”

Line 393-397 “So, the most cost-effective outcome will really be, again, to suspend something on the ceiling. The most effective frequency band coverage because we talk about this depth, you can't put something on the wall. So all those discussions come back to how much ceiling can we cover.”

Line 409-413 “...if we talk about cost acoustic ceiling is the cheapest thing to use because it is a suspending grid dropping tile and most contractors can do it cheaply. As soon as you start talking about something to put on the wall um... when even when I say fibreglass is cheap you cannot put fibreglass on the wall without protection.”

Line 431-435 “So, this will be the primary option (*only treating the ceiling and leaving out back wall treatment*) but then I know from the budget perspective will be the option of covering the entire ceiling and then the cheapest acoustic ceiling tile on the market is something called OWAcooustic Futura 60 and that's been sold and used in the country for the past 25 years.”

Participant 3:

Line 63-66 “I am going to talk about acoustic islands which is um... when you just suspend a piece of acoustic material (drawing). So I am going to draw this on the second ceiling plan. And I'd position them at the back of the classroom.”

Line 72-75 “So they (*acoustic islands*) would be suspended on hangers over here from the existing ceiling, the existing ceiling may not be strong enough so we may have to put it on some sort of a structure on the existing ceiling.”

Line 78-83 “So they would hang down like this at a bit of an angle and that would be made out of some sort of an acoustic tile – such like those that ecophon makes. Okay so ecophon stuff isn't the cheapest but you're only going to use a little bit of it. And it isn't invasive because you aren't ripping out the ceiling and putting in a new ceiling you can actually just put it over the old ceiling.”

Line 87-89 “Um... and you want it at the back of the class because that's where you want to minimize the most echo and feedback. So that's going to help with the reverberation.”

Line 128-133 “Because you also want to try minimize the

reverberation at the top on the sides and in the corners because that's where you often get kind of disturbing echoes where a vertical and a horizontal wall or surface come together so basically in the corners of your room. So I'm not going to add a lot of absorption on the walls because the windows are there but um... since these things are pretty easy to install I'm just going to put them on the sides as well."

Participant 4:

Line 50-53 "...you'd need to cover the entire ceiling with NRC 0.7 to achieve 0.8 seconds... it's a safe enough assumption to say if we put a ceiling in this space with an NRC value of 0.7 we'll achieve the reverberation time..."

Line 55-56 "...that's where I would typically start. Um... and to achieve 0.8 seconds is something I think without spending too much money is achievable."

Line 77-83 "This is a plasterboard ceiling and I think that's something you'd have to just get rid of. There's not much you can do with a plasterboard ceiling um... to improve its acoustic performance. Um... so once we, once that's out then there's a number of options of treating the ceiling. And I think that in my experience, the cheapest way to do that would be with an acoustic ceiling tile, a drop in ceiling tile. Um... which means they'll have to suspend a grid..."

Line 113-116 "With an acoustic ceiling tile, that's the ceiling tile itself does that acoustic absorption. So that's the advantage it's already um... you're already um... you're installing the grid and the ceiling tile, and that's it."

Line 120-124 "So from a cost perspective certainly in a classroom environment as well where you know um... we're looking for function, we're not looking for... um... you know in a corporate boardroom you might be looking for a particular look you know... in a classroom, you want something functional and not invasive."

Line 137-140 " ...the cheapest option we can go for is a drop-in ceiling tile and you know, from my experience that is almost always for a classroom environment, the best solution and we see it in a lot of new classrooms overseas, it's pretty much a standard."

Line 161-164 "...but I think personally for a classroom if we can solve a lot of the biggest issues here with ambient noise a full ceiling with Class C will be functional, we'll have a functional classroom,

and I think we will get to our target STI which for me would be no less than 0.7.”

Line 223-224 “...once we've installed the ceiling, for me um... we've done the biggest and most effective step for internal acoustic quality.”

Participant 5:

Line 160-167 “...I'd say the more you can get onto the ceiling the better... It's an easier space to treat because you don't necessarily have to cover it to protect it and um... and it's a big enough area to make a big enough impact on the reverb time. So... the typical usable space is 80-90% of the ceiling... so I'd say the more we can find on the ceiling the better. And try for a material that has an NRC that is bigger than 0.7. “

Line 169-170 “There's a material called Sinotex or Thermoacoustics might be even better, it might be cheaper.”

Line 181-183 “I'm sure they don't want to take out the ceiling and reinstall something else, just from a cost perspective. So it'll be easier and quicker to just stick it on to the existing ceiling it'll make a difference for sure.”

Line 191-193 “...you can either go for polyester, glass wool, fibreglass, mineral fibre, but I think this (*polyester*) might be cheaper and it has a great efficiency it's a great product. So I'd say take as much you can of that and stick it on the ceiling.”

Line 196-198 “...the more you can introduce into it the better just from a practical perspective it's not always possible to go up until the walls there's sometimes a 300-400mm gap, but if you can do it that will be great.”

Participant 6

Line 20-22 “So in terms of your scenario for a slightly more expensive ceiling change the panels to acoustic panels and in my opinion, in this scenario, it would improve the acoustics quite a lot.”

Participant 7

Line 29-31 “...if you did the entire ceiling you'd drop the

reverberation by quite a bit. You would get to 0.6 (*reverberation time in seconds*), ja probably around 0.6.”

Line 34-36 “...so when looking at the ceiling it is the cheapest, easiest, and fastest way of doing it um... that's in terms of reverb.”

Line 51-60 “So if you go Class C or less, then you start looking at (installing) wall panels and the rest of it. Ideally, you still want to have wall panels, um... but in a budget situation, you wouldn't. What we find um... even if you have an absorptive ceiling you find that you'll get an echo or a flutter echo between these two walls and those two walls. So you want absorption on each wall at least on the adjacent walls or two walls um... but uh I guess it can be done cheaply, the acoustic panels, um... we can certainly look at doing some acoustic panels at the back and the cheapest way to do it is timber frame, um... polyester fibre, I wouldn't go fibreglass... (writing and drawing)... you need a decent density which I can't remember off hand and a fabric over it.”

Participant 8

Line 78-85 “...acoustic drop-in ceilings... It's actually an acoustic board... but it is a gypsum I think it's got a bubbling texture.”

Participant 10

Line 42-43 “Remove ceiling and install acoustic lay-in ceiling so that would then be in a grid, which is cheaper.”

Line 46-50 “To fix an absorbent material, Class A, absorbent panels to existing ceiling... The pro here is that you work around existing surfaces, so you don't have to get an electrician in and you're not having to work around.”

Line 55-58 “Traditionally we would say from the manufacturing side of the industry you would have a lay-in ceiling with an acoustic grid ceiling tile is always the cheapest way to get the best performance. But that's from a blank page perspective.”

Line 78-82 “Absorption in the back 2/3rd of the classroom where the front is considered where the teacher is... And that's the back. So I would position over this void – and this would be option 2, absorption material, class A, and I would choose blown glass wool because that's been shown to be, it's high density...”

	Line 86-89 “So this is 1/3rd, it’s not exactly to scale and that would be 2/3rds so if this is option one these are all absorption panels and this is reflective ceiling so in this case, it would be the existing plasterboard ceiling and that would be to promote sound clarity and propagation.” Line 106-107 “...option 1 I would definitely look at the same type of split. 2/3rds to 1/3rd, uh and if we do whiteboard here, front, back, but this time it would be in a grid...” Line 110-112 “So if possible it can act as reflective existing ceiling board or... Reflective ceiling tiles and the great thing about that is that those are usually cheaper than the absorption.” Line 119-120 “...reflection above the teacher helps promote speech signal and the absorption in the last 2/3rd help absorb the reflection...”
Acoustic treatment of the back wall	Participant 1 Line 226-232 “...it's a plastic frame and then you've got the material or first of all you put the absorbing panels, you glue them onto the wall as well (drawing) uh... so that would be one thing and then obviously again with the fabric um... you... it's basically got some uh... some clamping mechanism so you squeeze the fabric into the.. Into that clamp and then you tighten the fabric. So the fabric is nice and smooth and then you get supposedly get one surface area of absorption.” Line 234 “...the high-density polyester...” Participant 2: Line 415-420 “Anything with a covering on the wall needs protection that can last okay... that also means that something is hardy especially in a school environment now if we use an extended contract fabric to cover fibreglass with a frame over... Ja, and that we talking about fabric and fabric in a classroom won't last. So if we talk about something that is more hardy like perforated timber or perforated metal that's more than R1000...” Participant 3: Line 92-93 “Some sort of absorptive panel on the back wall. Because that's also where you want absorption.”

Line 115-116 “There isn't much opportunity for absorption on the side walls because of the windows.”

Participant 4:

Line 228-232 “...the treatment of the back wall... um... and that is a secondary would come second to treating the ceiling because that's my most effective area to treat and the cheaper option per square meter. Treating the back wall is mainly for um... you know if you've got the teacher up front and you know depending on the size of the classroom...”

Line 236-240 “...you certainly can improve the acoustics of the room by introducing something on the back wall which just prevents that you know that extra energy that's coming back to the ‘stage’ coming back to the learners off the back wall. Um... so in terms of wall treatment that's the only area I would consider.”

Line 264-268 “...get your main contractor or a shop fitting contractor construct wall panels which is um... it's a fairly simple detail. We typically say we use timber brandering which is basically a square timber profile. And um... you use the timber brandering to essentially to create the framework and to create a gap behind the finish.”

Line 268-280 “...typically you'd use a fabric finish, something like a valcan fabric from Weavers World which is the cheapest fabric finish you can probably get.... you use a timber brandering to create a framework and we add an acoustic insulation behind the material finish.”

Line 308-311 “So that would be second priority back wall treatment if um... there was funds available um... but certainly, ceiling is priority. Um... so those two solutions would be an ideal classroom environment for me.”

Participant 5

Line 210-213 “...that (*acoustic panels on back wall*) will also obviously help with the reverb (*reverberation time*) and increase the speech transmission. Um... but it'll also help with the slapback for the teacher, I don't know if you've noticed that for some... with hard reflective surfaces it's a very quick echo, so it's not technically an echo but...”

Participant 6

Line 36-42 "...if we can treat that (*the back wall*) with an acoustic material and there is a couple on the market and I didn't think of what we can use there but even if it's a felt or... and what is nice because it's a dual function is if you use a pin boards with a cork type material it actually absorbs sound so if you start with that whole back and start putting pin boards on there than it actually absorbs sound because your sound from the front actually like goes in that direction and I mean your biggest is the back wall over there."

Participant 7

Line 59-60 "So you want absorption on each wall at least on the adjacent walls or two walls um... but uh I guess it can be done cheaply, the acoustic panels, um... we can certainly look at doing some acoustic panels at the back and the cheapest way to do it is timber frame, um... polyester fibre, I wouldn't go fibreglass... (writing and drawing)... you need a decent density which I can't remember off hand and a fabric over it."

Participant 8

Line 50-52 "...pin-up panels with soft materials for um... for some absorption, the only reason I'm using the back wall is because there isn't a lot of space on the sides."

Line 56-60 "...I would probably use a um... an MDF board or something with foam... a timber board and wrap the whole thing with like a felt an absorptive felt um... so... felt fabric (writing)... um... you can also use there's these absorptive panels, it's more like a gypsum type panel that you can also use..."

Line 67-71 "Those ones you can also have them on wheels moving around so that if the children are... if this is loose furniture and it gets moved around you can easily have them let's say... if we take out some of these and move them slightly forward (*Referring to the back row of chairs*) you can actually move these panels around to wherever you need them. "

Line 170-172 "... some sort of makeshift hanging panel, they do that a lot in auditoriums around the back. Um... but that's also... I'm not

sure if that's to reflect sound or absorb it..."

Line 179-182 "...be a few acoustic panels and then you have a lot less... acoustic panels (drawing)... or um... something like that... it's like a high-density foam more than a sponge... what did I use, the word... at the beginning of those panels..."

Participant 9

Line 78-81 "A dado rail is a piece of drawnary that you stick on the wall and then what I would suggest doing is something putting something soft like material... like felt or something like a pinup board in this area... so if you don't want to do the entire wall of it, you do it at a sort of dado rail height."

Line 86-88 "...use felt or some sort of upholstery material something like that... what you can try to do for these as well is actually um... get loose pinup boards that you can stick up on to the wall."

Line 90-93 "You can do cork or you can do you actually do panels that are sort of like pre-covered with upholstery material so it's almost like a headboard in your bedroom, it's upholstery material and this then is just um... like a piece of plywood or whatever piece of timber..."

Line 98-103 "I would do it on both (*walls*), you try and sort of maximize whatever data that you can... throughout so all the way through, it's only going to go up to um... your window height, obviously it won't be by the door... but do it all the way through... Right around the classroom, it gives it this nice soft edge... um... and then kids can come and pinup stuff up here..."

Line 150-152 "...I would cover about 80% of the walls and these can double up like we said with cork um... or with um... upholstery material or felt..."

Participant 10

Line 120-128 "...the back wall which is this cross section. I would put either position acoustic wall panels and I'm going to do like an option one and option two. So this could be an acoustic wall panel and this would absorb reflections off the back wall. The great thing is that you can those that are also pin boards so if we talking about cost, to bring down cost um... Is to make things work harder so if

	one thing is one thing and another thing um... Then you get some cost-effectiveness out of it. So I would do an acoustic wall panel which helps the kids particularly in the back third of the classroom to not get um... Late reflections from the back wall.”
Carpets/flooring for reverberation absorption	Participant 1 Line 460 – 466 “...carpet... it does help with absorption um... but it’s got its limitations in terms of proper absorption... any type of softer material adds to the absorption which will obviously improve the sound inside the classroom... the carpet doesn't have to go all the way to the back, just maybe in the front where ja maybe from the front wall to where the first chairs start.” Participant 3 Line 33-35 “...let's go with carpets um... so a mat in a reading area might be... it would help add to the absorption... let's go with carpets on the floor sort of an office type carpet that's hard wearing.” Participant 7 Line 76-84 “Carpet the whole floor, carpet isn't going to give you much but it helps a little. Um... commercial grade... carpet tiles... the tiles and the curtains won't do a huge amount it's really the ceiling and the panels that are doing the work... it's not the actual curtains that are doing the absorbing it's the air gap between the curtains and the window.” Participant 8 Line 24-27 “So um... firstly what we are doing currently, but this is a more expensive one is floor finishes so on plan I'd say we have moved away from plan because it's too hard, as well as not good for kids to play on. A softer floor finish like vinyl flooring is something we've been using a lot the more expensive ones.” Line 73-75 “Um... a great floor finish would be carpet tiles, but the problem is a maintenance issue, so um... so you can have loose carpets in areas where there is a big problem, but it is high maintenance thing, unfortunately.” Line 101-108 “...loose carpets is an easy one... Um... then natural materials are also good, shelving and things like that. Stick to natural

	materials like wood as opposed to steel that's also quite good, the thing is just maintenance one again, so schools are reluctant depending on how big the school is and things like that.” Participant 9 Line 47-48 “...introducing carpets in our classrooms... some carpets and then we always have a need for pinup spaces um...” Line 51-53 “Loose carpets will probably work out a bit cheaper but it might not be the best application it might be better to just put a burber... it might last longer...” Participant 10 Line 313-328 “...a vinyl is a reasonably cost-effective way of doing it especially like a single surface vinyl, so not like the clack clack clack vinyl flooring... it's also quite hard wearing so that could be quite a good option for a school um... What's quite good is that that can be laid over whatever is existing um... but it would probably be more expensive... Carpet tiles or vinyl flooring... that could possibly be cheaper... carpet tiles can sometimes be a bit... but especially in grades 1-3 where you're getting kids to sit on the floor, it's quite nice because you have a bit of a thermal um... it's not a cold material... use carpet tiles so that you can replace one, so actually strip but yes at least here... the key thing would be whatever material doesn't generate that much noise by moving furniture or walking on it would be key...”
Health hazards with using mineral wool as absorption material	Participant 1 Line 66 “...The mineral wool, if you looking at classrooms and children and health and safety and all that kind of stuff.” Line 72-73 “...after a while these fibres they um... tend to break out and obviously then start to um... drift around in the environment which is then obviously not...ideal” Line 76-77 “...for health reasons and people, start, especially children start to breathe in those things.” Line 79-83 “...from a health and safety side um... it's not the ideal. So um... therefore if you would go for um... absorption material that uh would then I would recommend using the high-density polyester. Um... because it's more, it's made from plastics on that

	side it's not um... ja you don't have these fibres floating around in the air.” Participant 2: Line 365 “...but even fibreglass I know many people are quite sensitive.” Participant 4: Line 289-306 “...glass wool is typically the cheapest... glass wool is obviously it releases fibres so when it's unfinished it can be a problem and it can be dangerous especially in a classroom environment... polyester fibre might be more expensive.”
‘Home made’ panels for ceiling and back wall	Participant 1 Line 106-108 “...a normal building contractor could or a basic carpenter would be able to put these things together and then just suspend them from the ceiling.” Line 112-117 “...high-density polyester panels...”, “...wooden frame...”, “...butchers linen...” Participant 3 Line 99-110 “I'm going with home-brew stuff okay... buy batting which is basically like stuffing that you would like make a duvet or quilt out of... I'd staple material to the back – any kind of material. Um... to stick batting to the material and then I'm going to get felt material and I'm going to cover the whole thing with felt which will give you a lot of absorption.”
Curtains	Participant 6: Line 42-49 “... the best treatment for acoustics is normal curtain and I know curtains aren't a traditional thing that you put into a classroom but on the two back windows if you put curtains on in there and curtains are better than blinds because blinds, curtains are wavy and absorb sound better whereas blinds although it does absorb sound okay the blind basically sits like that so if your sound comes in it actually does reflect it and absorb but a curtain is a good sound absorption.” Line 51-53 “...if they (<i>the curtains</i>) ... on the back window yes they

need to be closed but even if you push them to a ¼ there and ¼ there it would drastically improve the acoustics there as well. Because obviously if you close it the light becomes an issue.”

Line 66-71 “So um... ja if your curtains go all the way up and they don't have to be closed permanently it would actually help in that scenario. But even on the back wall, bookcases with books will help as well. So if you start populating a classroom, it'll help. Actually putting um... the kid's art projects on the walls or hanging them from the ceiling I mean if they did like spaceships or whatever and they hanging from the ceiling they actually help with uh... acoustics.”

Participant 7

Line 76-84 “...the curtains won't do a huge amount it's really the ceiling and the panels that are doing the work... it's not the actual curtains that are doing the absorbing it's the air gap between the curtains and the window.”

Participant 8

Line 186-190 “...curtains or blinds, but I'd say um... what do you call it... a roller blind – a fabric roller blind to have more soft materials in there... um... but the thing is you're never going to leave it closed so... you actually get really beautiful ones nowadays, you can also get semi-transparent ones... um... that still allow light in.”

Participant 9

Line 67-73 “...add a curtain or something just so you can absorb some of the sound the same kind of effect here, if you can try and sort of try get the blackboard here even though it covers some of the windows you can try to do that. It's not the ideal space, this is the best space for the blackboard um... but in terms of that. But definitely in terms of noise, it'll definitely work better this way... um... and there's always need for pinup spaces in classrooms so to try and maximize your pinup spaces and try to sort of like a dado rails...”

	Participant 10 Line 207-211 “A curtain over here, what it would do, it would provide diffusion so redirecting the sound... so in a classroom um... to improve the room acoustics of the space you always looking at absorption elements that help reduce the sound energy or prevent reflections or diffusion which helps scatter sound in a more comfortable environment.” Line 217-223 “... so quite often people will say like curtains may help reduce the sound pressure level, it won't actually... it will only reduce certain sounds which are almost masked out by your mid and low-frequency sounds anyway... so it does help with diffusion and it also does create some um... high-frequency absorption... it does help with some perceptual privacy so there's more what a curtain is classically designed for limiting light or so you don't see kids walking past or um...”
Egg crates	Participant 6 Line 77-81 “The best um... sound absorption is actually egg crates... And I mean its cost effective egg crates on that back would make such a huge difference on your sound and that's a cost-effective way hey. Each pupil can bring one and then you like halfway there.” Line 83-87 “So you could actually put the egg crates in between the pin boards or on that wall over there on section CC so um... ja... and on the front where the blackboard is actually having egg crates on down there and I'm not an acoustic engineer but I feel that if you can sort out the back then you have less of a problem than having it on the front.”
Shelving and other absorptive furniture	Participant 8 Line 200-201 “...shelving and things like that and soft elements in there... but you'll probably have that anyway... cardboard models and projects, toys...” Participant 9 Line 18-19 “...in terms of furniture, chair bags... more absorption qualities...” Line 43-45 “... getting chair bags, the chair bags will add some softness to that... and maybe have in the corners of the classes some bean bags or just sort of reading corners and um... just to try and

	absorb some of the sound...” Participant 10 Line 153-158 “The second thing is to diffuse so things like bookshelves on the back wall, um... so any kind of furniture that could help break that reflection and create sound diffusion and break it towards the ceiling so that it can be absorbed. It basically helps the ceiling function at its maximum capacity rather than just the sound that interacts with it through incident bouncing of sound... so this would enhance through diffusion it would redirect sound toward the absorbent ceiling.”
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Table 3

Acoustic treatment suggestions to improve the ambient noise level.

Dominant Themes:	Excerpts from the interviews:
Too expensive to conduct sound insulation	Participant 1 Line 169-170 “...your ambient noise coming from the outside to the inside we are dealing with soundproofing...” Line 331 “Um... ja low cost that is a bit of a tricky thing.” Line 333-334 “...the way to increase your soundproofing would be to add mass or weight to the surfaces or to the boundaries...” Line 468-486 “...ambient noise levels is driven by typically two things. External traffic noise or human noise, or mechanical system noise. Luckily, or not luckily... most of these rural schools don't have mechanical ventilation... that's the biggest noise generation... In rural schools, it's just about noise outside in the sports field or the main road.” Participant 2 Line 540-541 “... there isn't much we can do due to the current structure in terms of reducing ambient noise levels.” Line 548-549 “And stopping sound you can't have something that is porous it has to be solid and uh... curtains aren't going to help you.” Participant 3 Line 89-90 “We will get to the (<i>sound</i>) isolation just now. Because that's more difficult to deal with.” Line 153-154 “But the outdoor noise is going to be a problem. And there is very little that we can do about that.” Participant 5 Line 128-129 “...for the ambient noise levels, because there is an existing structure there are massive limitations...”

	Participant 6 Line 96-97 "...I know it's hard to do sound insulation on a low cost." Participant 9 Line 117-118 "It's really difficult because the only way that you're really going to stop the ambient noise from coming in is if you close these windows or if the windows are of a high spec... it's very expensive to do that..."
Windows and doors	Participant 1 Line 335-344 "...because you've got a glass that would be your mostly your weakest link between the outside and the inside. So one way of improving the soundproofing would be to add a second layer of glass um... that would be one thing... and then you can also have a look at the door. Obviously, because doors are opening and closing so um... there's also a weak link because around the door you've got some spaces where sound can actually come from the outside to the inside. That is... so... so you can have a look at how the doors and the frames are they actually sealing when the doors closed um... and then one could use some uh... yea depending on the space or how much space you've got between the door and the frame you could add some rubber seals." Line 347-448 "...so that the sound or the less sound goes through the space between the door and the frame." Line 398-399 "...glass is more expensive than plexiglass so one could maybe use, put a sheet of plexiglass on the inside of the glass pane..." Line 405-407 "...adding thickness to the glass and you're adding some air space between the two glass panels so that improves the soundproofing as well." Participant 4 Line 448-450 "...we're most likely looking at is flanking through these windows um... so coming out through the windows and back in through the door or the windows. If

sounds from other classrooms are being audible that would be the issue.”

Line 462-469 “If it's the steel windows that I'm thinking of I really wouldn't expect more than 15 you know 15 dB reduction when it's closed when it's open it's practically nothing because you've just got direct sound transfer um... so you can immediately see that we've got an issue um... and it's the same with the door, with an unsealed... so with a door without any seals, if it's a solid core door, which these old-school classrooms it's typically a solid core... you know it used to be an easier thing to do. But it might even be a hollow core door. Um... but without the seals and anything like that you know at most we can expect about 22dB...”

Participant 5

Line 91-108 “...we can put seals on these openable windows which would help to an extent... For when they're closed, but obviously when they're open there's not much you can do except from a management perspective and try to manage this sports and recreational area activities, keep that to a minimum because that is closer than the main road... Like a neoprene, compressible rubber seal... typically... but it should be well installed obviously so when the seals come to a corner they should try and overlap. Because a small leak in a structure can compromise a whole lot in the sound insulation.”

Line 109-110 “Seals for the door as well for when it's closed, but like you said it's open for the most part.”

Line 117-119 “I guess what might help is to have a vent on this door, instead of having a big open space, have the door closed with a vent that might help a bit”

Line 123-125 “Because it is a smaller opening (*referring to the vent on the bottom of the door*) there will be reduced noise coming into the classroom from outside, but with all the other leaking points, who noise how much difference it'll make.”

Participant 7

Line 91-96 “...then we start looking at the more difficult stuff... isolation... the biggest problem with isolation is your

	ventilation your windows have to be open, and the door is pretty much always open... so... uh... realistically if you really wanted to do this the door becomes a solid timber door... with seals rubber seals..." Participant 9 Line 118-119 "...um... the only thing I can kind of think of is sort of manually managed when there's sports outside, just to close the windows and try to stop that from coming in..." Participant 10 Line 200-204 "The one thing here is you know... from a sound insulation point of view... I would not change the windows and door um... even though that would improve SI (<i>speech intelligibility</i>) uh... it's too costly for impact again... and if culture/climate is to open windows then it is superfluous. So ideally absorption would be on this wall, but there is no opportunity for it..."
Shutters/curtains	Participant 3 Line 198-209 "On this side, there must be solid shutters on the inside because we aren't doing any external well... we did do external stuff there, but let's keep it on the inside because then it doesn't have to be as weatherproof. Solid shutters that can be closed only when there is PE going on outside. So they don't have to be closed permanently but just in that one period where they need to be closed. Um... closed when necessary... They are simply made out of um... composite wood... should be high density and it's not very expensive" Line 211-220 "...high density helps with isolation... So you would probably make a bit of a timber frame just to mount them on." Line 230-235 "...3 sliding panels that can slide over each other. Like sliding doors but against the window... So if they're sliding that's also quite nice because that means that you can slide one open so you can get some ventilation and the other two can be closed so you still have a bit of control."

	Participant 6 Line 109-111 “... your curtains on your windows or blinds will actually help reduce your sound coming in from the outside as well.” Participant 9 Line 122-123 “...but I definitely think if you add something like a curtain or something like that it'll help just to absorb a little bit of that noise.”
Replacing fans	Participant 4 Line 89 “...replace these fans...” Line 216-220 “...direct ingress of external noise and the fans that's the issue. So you might see a 3-4dB reduction in ambient noise level, just because you have more energy absorption in the space. But that doesn't help at all with the direct noise coming off that fan to a student or through the door or through the windows.” Line 360-368 “...the structure because assuming that we now assuming that these fans are past their date... they're too noisy now um... we need to look at an alternative solution either with newer fans which aren't rattling um... and you know you can use them... So they'll need to be replaced, the fans will need to be replaced.” Line 409-417 “Well I think ja like you said in summer another huge aspect of teaching is temperature, it can't be blazing hot or learners fall asleep. I think it's important to have at least air movement with an openable window perhaps which is not the ideal solution because you're obviously much more vulnerable to external noise but with this kind of classroom, that's what will be there... let's replace the fan with quieter ones... put in quieter fan units and again even if we're running them at medium speed they're not as noisy as at full speed, so we're looking at maybe a compromise.” Participant 10 Line 61-65 “So replace fans to quiet fans... And if that’s the case and there’s already some sort of service disruption or

	reinstallation then I'd probably say the first option one of replacing the ceiling because I think from a cost perspective a cost to benefit that is going to be the cheapest for the most benefit if there will be some other um... Intervention..." Line 278-282 "...if you don't have fans you don't have any fresh air supply which means you actually cannot close the windows because now you have a carbon dioxide increase so you might be improving the disruption level, but now your kids are getting less oxygen."
Behavioural and School management	Participant 1 Line 388-391 "learners playing sport during the learning time, then I would maybe just see, can't you then get the learners during the learning time just to have like another space or place where they can play instead of playing next to the classrooms" Participant 2 Line 479-482 "And that's (<i>ambient noise</i>) much more difficult to solve because noise is carried by air and if air can flow sound will flow. And if we block this up, the window cannot be closed because there needs to be a cross flow of air. So I think that it probably has to do with planning." Participant 4 Line 338-353 "In terms of the recreational area and the sports field, those are things that can be managed from a school management perspective you know it sounds simple but when there's school you know, underway... you know this should be a quiet area. The recreational area should be a quiet area until its break or until it's after school hours likewise for the sports field. Typically the sports field would only be used after hours except for physical education. Um... but PE would be an issue, but that's something that maybe um... the only realistic way to manage that would be to... say that the PE teacher needs to manage noise levels and I know kids will be kids and they will play... you know um... you know try and maybe get as much distance as we can um... mark out a particular area for PE that's you know... in this corner for example (drawing) then we can

try maximize our distance to the classrooms, but really it comes down to a management thing if we can probably say we do have concurrent teaching happening in the classroom and PE then PE needs to be you know... we can't be going 'ballistic' in terms of noise levels... And that requires the headmaster and that requires rules, etc. etc."

Line 523-529 "Um... so in the South African context, it's unlikely to see that and unlikely to be a viable option. So I think the best solution here would be to try and manage, if we can manage, the noise from the recreational area and the sports field and if it's at all possible to try get the wall put in to try and reduce the main road noise um... and we can reduce the ambient noise level from 70dB to 40-45dB we can, our teachers can start speaking quieter, or teaching at a quieter level and we get less you know... interruption between classrooms, you know less noise moving between classrooms."

Participant 5

Line 108-109 "...management all in terms of trying to keep down the ambient noise levels of the classrooms."

Line 127-128 "So it might just be a cultural thing that can be taught in the school assembly to try and be quiet or quieter if possible."

Line 310-312 "...to try and get the kids to suppose be more considerate of their own noise levels but it is a primary school and that isn't easy."

Participant 8

Line 207-209 "...the school also needs to manage their timetable so that there isn't a lot of traffic while there's classes going on... I'm not too sure how to manage that..."

Participant 10

Line 136-143 "... that there is a behavioural component to it always because the signal-to-noise ratio is quite set i.e. if the noise level is at x you're needing talk x-amount of decibels above that in order to be heard. As the ambient noise level rises

	so you're having to talk louder to be heard and the ambient noise level continues to rise. So if you keeping it quieter people produce less noise to be heard so there's a behavioural component which is very hard to actually capture in the environment around it because that sits more in the almost like a bonus effect that you get from a behaviour point of view.” Line 269-271 “I'd rather look at cultural things so like how is your scheduling done, how is the timetable worked out, so that almost that disruption is controlled in terms of the activity so...” Line 273-276 “... maybe so moving activity around and using programming culture uh... those type of things, to control your sound insulation as much as possible, because acknowledging sound insulation in order to permanently seal these classrooms off.”
Improving ambient noise levels to increase speech intelligibility	Participant 4 Line 494-511 “...instead of trying to improve sound insulation if we can bring the ambient noise level down, we can start to improve the transmission of noise between classrooms. So um... it's impossible to quantify what we will get with the new fans but if we can get into the region of 45dB's then we can get a teacher speaking at 70dB you know... so if that's not the issue it would be the flanking through the windows. Um... I think if we can bring the ambient noise levels down and get the teachers to speak at a reasonable level, we can – we might not eliminate noise between classrooms, but it might be to the point that it is manageable. Where we might have, it might be audible but it won't be understandable or intelligible... just a muffled sort of thing that you might be able to hear. That would have the least impact on intelligibility, as soon as you've got noise with someone shouting across the way for example, and you can hear what they're saying, it muddles what you're trying to hear from your teacher. Whereas if it's an unintelligible noise, we might... it has less of an effect on speech transmission and intelligibility.” Participant 5 Line 39-41 “So the higher the ambient noise level is the higher you have to raise your voice. There's a limit that you can raise it to so than in between that you have to try and teach, so obviously the lower this is the easier it is to hear what's going

	on.”
Rearrangement of the classroom	Participant 9 Line 32-37 “... you have noise from the corridor here and then you've got noise from the sports field over here... on the left-hand side, so I would actually turn the chairs around so that your view is actually towards the corridor even though you... because at the moment you... you're hearing from this side and this side... whereas if you turn it around you'll sort of have your back against the sports field and look towards this space.”
Flooring	Participant 10 Line 307-312 “...metal on a hard floor usually generates a lot of noise so either rubber footing furniture so that by moving desks and so on you're creating less noise that you're having to absorb somehow. Or by changing the floor surface and there it would it would need to be something a floor, often people think that an acoustic floor is going to absorb sound it's not a floor to absorb sound it's a floor to make sure that sound is not generated.”

Table 4

External treatment suggestions to improve internal acoustics.

Dominant Themes:	Excerpts from the interviews:
Barrier around school by road	Participant 1 Line 380-383 “...with soundproofing and acoustic treatment it is uh the best way is to treat the source if you can treat the source you obviously you don't have sound moving all over the place okay... so one way, this is more a long-term solution if it's like next to a busy road uh one could plant trees next to the road...” Participant 7 Line 158-161 “...making something like a brick wall on the boundary instead of an open fence... um... this is the site plan... put a brick wall on the boundary...” Participant 9 Line 171-173 “...some sort of landscaping buffer here with quite tall trees um... and the same kind of thing on this side, just so that they that gets absorbed a little bit... um... but more than that you can't really do...” Participant 10 Line 223-226 “...trees, trees don't really help any sound from the road but they create a visual barrier which somehow helps us separate the sound from the visual and we get less annoyed by it but it doesn't actually reduce it...”
Barrier outside classroom by sports field	Participant 6 Line 99-102 “... but if you can put a barrier like a hedge growing there then it would make a huge difference. Just like it's the same thing with the sound here where um... basically gets absorbed by the hedge and even here with the sports field either trees or hedges along there.”

	Participant 7 Line 162 "...and certainly look at putting some sort of barrier almost the whole way on the sports field... Brick can do... um... timber will do..." Participant 8 Line 113-116 "...a lot of landscape architects tend to plant trees in areas in between somewhere where they want to reduce the noise and the highway for instance. But it's not that effective, it's better than having nothing, but it's not as effective because it's not a mass. Um... something like a berm which is soil mass is much more effective." Line 121-124 "Um... ja it wouldn't be sand though, it would be soil... like fertile soil... what a burn looks like... let's say sports field is that type thing well you can even do it a little bit or less of a slope and then straight down and then you've got the building behind here and whatever height you need..." Line 128-130 "... kids can sit on it play on it, it can become a bit of a mount... so that's only if they have budget for landscaping or um... so that can become quite functional..." Participant 9 Line 171-173 "...some sort of landscaping buffer here with quite tall trees um... and the same kind of thing on this side, just so that they that gets absorbed a little bit... um... but more than that you can't really do..."
External acoustic treatment	Participant 1 Line 170-176 "...options for outdoors... hm... so you could add an acoustic ceiling it would be costly um... but probably the best option you've got or even to add panels similar to the ones we made for the back wall. Yes, let's do that go budget. Add absorption panels to soffit (underside of corridor slab above). Um... similar to homemade wall panels. So that's going to help the noise that enters this corridor not to bounce around and enter the classrooms. So it actually won't bounce and it will be captured. So it will reduce the noise in the classroom."

Custom made absorption panel outside window	Participant 1 Line 433-439 "...if the window opens like this okay, if you put like like a type of build like an out of metal and preferably like perforated metal like you've got a metal plate with holes in so you've got like a box, and you put the absorption material inside and you cover it with perforated metal and then the sound that actually um... comes through the window and the bottom will be absorbed by this box. And then less sound will actually go come in the window."
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Table 5

Acoustic treatment suggestions in the ideal situation.

Dominant Themes:	Excerpts from the interviews:
Mechanical Ventilation	Participant 4 Line 143-145 “We not looking at mechanical ventilation I don't think it would be able to be a viable thing to put mechanical ventilation in this kind of space...” Line 369-375 “...um... in terms of mechanical ventilation for example, um... I just think that the cost associated with... will be too expensive for um... you know certainly, I think, let me rephrase it, I think that ideally, that should be the best practice solution is to have in a classroom a mechanical ventilation where we can introduce attenuation and we can control noise levels um... by having the right infrastructure in place so that would require if it's a fan coil unit that they're using which would be an internal you know...” Participant 5 Line 319-325 “So... I think I think if the reverb situation is sorted you've done really well... from an ambient noise level perspective, it's always an issue. I think it's always going to be an issue unless you start air-conditioning the rooms and start keeping everything closed and have like a private school environment where it's a different culture. But for the masses, I don't think it's ever going to be ideal, in an ideal state. So... I think the area to focus on is the reverb so at least they can understand what is being taught.” Participant 7 Line 172-174 “... you need air conditioning or some sort of mechanical ventilation with an attenuator... and that comes at a cost... um... and they're not on all the time so...” Participant 9 Line 168-170 “...in an ideal world ja, I suppose you would like

	to really change a couple of things, you'd rather have double glazing, aircon so that you don't have to deal with the noise but it's just going to be too expensive..." Participant 10 Line 31-33 "...fancy mechanical ventilation systems that always have their door and windows closed then it becomes a different thing."
Exchanging windows and doors	Participant 1 Line 480- "...we talking budget obviously there are more things that you can do to a classroom or to a room but um... for example, adding like a dry walling... silicone the frames closed and that already made a big difference, but obviously now if you silicone them you can't open them anymore." Participant 2 Line 503-505 "...so if the windows are here you can still have cross ventilation this way. And it will be a noise barrier like this and we can also introduce light shelf that, we make sure that, light is bounce, sunlight is bouncing off like this." Line 527-530 "...like you're already encouraging visual distraction I would actually say, block a portion of the window and allow a portion to let the light come through. If you can actually have the top portion to be openable and the lower level actually just block out." Line 551-553 "... you can properly seal the windows if you can get standard glazing 6mm is about 30dB but only if the rim can be properly sealed." Participant 4 Line 26-28 "In terms of a low-cost solution that is an extremely difficult thing to do um... the structures are in place um... to replace windows, to replace doors, those are hugely costly exercises." Line 453-462 "Um... if we have mechanical ventilation that means that we can get rid of openable windows which

immediately makes our sound insulation performance a much easier thing to manage without an openable section in the window, um... you know we can look to achieve, depending on what glass we put in we can look to achieve an excess of 30dB's of sound insulation. Let's say R-W which is a field measurement of sound insulation, that's a weighted reduction. Um... so, if we had mechanical ventilation, we could put uh... you know... we could replace the windows with non-openable window sections, um... you'd still be able to get a comfortable environment and we'd immediately improve our sound insulation with the existing..."

Line 489-493 "...it's not surprising that there is flanking between the classrooms and you are getting audible noise between classrooms. So if we can replace these windows, and you have the mechanical ventilation, we can dramatically improve that. But I really don't believe that that will be a viable thing in a state school of this sort of nature."

Line 512-515 "... realistically, I think to change these structures, to install new windows maybe with an aluminium profile, even if it has openable sections but it has seals on it, for example, is massively costly. Um... replacing doors, you know even a solid core door, you know a new solid core door with seals you're looking at R7000-R8000 per door."

Participant 7

Line 100 "...solid timber door..."

Line 116-118 "...so again it's a difficult one because we'd never do that and there's a maintenance issue with this... issue with the door (writing) um... and we get the windows... you could do the same thing..."

Line 120 "Well we'd change the glass out um..."

Participant 8

Line 90-97 "But the difficult areas is your windows. And you get a similar thing for windows, where all our traditional windows are one single glass pane like these but with a green star ratings, the new laws with a new build or a refurbishment you have to place it with at least a certain specification level and

	most of the things turn out to be very expensive glass or what is called double glazing which is a frame with two pieces of glass. And that is quite effective as well, and that also has an acoustic rating to a certain degree. But wait, one second, that isn't one of the cheaper options...” Line 139-143 “...on the entrance side I've located all of them (<i>the windows</i>) at a higher level but it's also because I have my blackboard there so you have windows above but the teacher can still stand there facing so having windows at a high level of the entrance side towards the recreational area will help with noise...” Participant 9 Line 118-119 “...if you close these windows or if the windows are of a high spec... it's very expensive to do that um...” Line 168-170 “...in an ideal world ja, I suppose you would like to really change a couple of things, you'd rather have double glazing, aircon so that you don't have to deal with the noise but it's just going to be too expensive...” Participant 10 Line 17-20 “Sound absorption and my stance would be that to improve sound insulation significantly would not be considered a low-cost intervention. So on the outset... So I guess that's my first point because the SI would need to be a new door and door frame of a significant spec and replacing all the windows.” Line 227-233 “...road noise and the children walking past and the sports field and the recreational area those are all sound insulation issues so that's all sound happening outside the classroom and will be coming into the classroom through currently if the windows closed, a poor window construction and a poor glass construction would only be fixed by using double glazing windows that are highly sealable. Double glazing construction is like that. Um... so in order to limit that sound disruption, it is quite a high cost which is why I say...”
Complex ceiling designs	Participant 2 Line 424-426 “And that's why if we have money this is what we would do (<i>horseshoe ceiling and back wall panels</i>). But if we

	don't have money then I will do put ceiling in here (drawing) and then we don't do this (<i>full ceiling with no acoustic panels on the walls</i>).” Participant 3 Line 51-55 “So for ceilings (drawing) number one would be to replace with acoustic ceiling tiles. Acoustic tiles... that would be quite invasive as it would mean ripping out and putting in and probably quite costly because ceiling tiles especially acoustic ones are more costly than regular ceilings.” Participant 4 Line 145-164 “So um... there's no reason that we can't do 100% coverage um... and in terms of selection of a ceiling tile the market used to be that you know you got an acoustic tile which pretty much was a standard NRC 0.7 um... acoustic ceiling tile... the advantage of using a Class A ceiling is that per square meter we looking at about a 20% more efficient ceiling” Participant 9 Line 190-192 “... in an ideal world it would be great to put in some sort of acoustic board above the ceiling or replace the ceilings with acoustic boards but it's just not going to make the cut...it's going to be too expensive.”
Wall barriers	Participant 3 Line 188-196 “So for outdoor noise, there isn't a lot that can be done. And on the sports field side, there's even less that can be done. Um... because there's no opportunity to add absorption or anything there. Um... one could but that's going to be expensive, one could try and add a wall let's say about one and a half meters away from the window but it would have to be at least 3 meters high, which is high, it's higher than the classroom. Um... and that becomes expensive and difficult and it's going to help the upstairs classroom. So I'm going to say that that isn't a feasible solution, it's a solution but it isn't feasible so I'm going to rub it out.” Line 250-251 “No but obviously in terms of the road noise you

	could put up a screen wall on the actual boundary of the school um... ja but that's beyond just the classroom design.” Participant 4 Line 326-337 “...change it from a palisade fence to a solid wall okay but that again... um... you know I think you'd get a 15 to maximum 20 dB reduction in noise level because you've still got... you're still going to have flanking noise over the top of the wall and also that barrier becomes less effective at lower frequencies... The 15 dB would be a good estimate at how much let's say a maximum for let's say a barrier... Um... and that would be the ideal solution for the main road and other than that there isn't much that can be done about management of the main road that's something we can do.” Participant 5 Line 314-317 “Anything more is going to be a big cost, it depends on how much noise pollution you are experiencing from the main road. You do get noise barriers that can be installed but once again who's going to pay for that? The school isn't going to do that.”
Flooring	Participant 6 Line 117-123 “Carpet for acoustics is the best but then from a maintenance point of view and I mean traffic the type of carpet that you need to put in there will be very expensive hey. Um... your normal is a vinyl type product that you put in there. Recently in a school we actually put a vinyl in that actually has an um... like a soft layer underneath it so that helps a bit because it's not just your concrete with a vinyl um... on top. But it starts to become very expensive.” Participant 8 Line 26-27 “A softer floor finish like vinyl flooring is something we've been using a lot the more expensive ones.” Line 37 “Obviously, if you have to refurb a school it is a big expense...”

Table 6

Acoustic norms.

Dominant Themes:	Excerpts from the interviews:
Reference unknown by participant	Participant 1 Line 212-213 "...we need to bring the reverb time down to round about 0.6 seconds. Um... even if it's 0.8 that is your, your borderline value for this size of the classroom." Participant 5 Line 43-48 "Um... I think for speech in terms of reverberation rates, 1 second at the most 1.2 seconds but at 500Hz that's a good frequency range to take into account... Because that's where most of the human speech is based around, I think it ranges from about 250 to around 2000Hz?" Participant 6 Line 149-153 "No not on acoustics, a classroom is the only norm we use is the size, and that gets depicted by um... the client that we actually we use and um... we do government schools and private schools um... look here the last... the... in government they've actually said you know what this is the standard classroom this is the size of a standard classroom and even this is the finishes as well hey..."
South African acoustic norms	Participant 2 Line 70-71 "...within this country, we don't really have um... standards for reverberation time we have standards for ambient noise levels." Participant 4 Line 31-38 "I would use the SANS 10103 where the maximum noise level for a classroom is 40dB. That's maximum um... and that's where our issue is and unfortunately in South Africa, locally we don't have a standard for reverberation time in terms of the national standards, SANS. So what the industry generally uses is the Australian national standard and the Australian

	national standard references 0.8 as a maximum point 0.6 to 0.8 is the range of reverberation time for a classroom. Um... and that's also reflected in the green star the Green Building Council of South Africa has a particular tool for the public in education buildings. And in that tool there are some, it's an optional thing, first of all, GBCSA the Green Star rating of a building is an optional thing it's not a national standard or anything like that but it is a reflection of um... for the most part good design practice so for a classroom they also say um... 0.8 they give you two options either achieve a reverberation time of 0.8 seconds or to um... take if you can cover the surfaces of a classroom with a minimum of the ceiling area. So either the total ceiling area or more, on the surfaces of... whether it's on the ceiling or the walls so if you need to have a bulkhead of around the ceiling you can add additional treatment on the walls and the minimum performance there is 0.7 NRC.” Participant 5 Line 248-260 “...1.2 (<i>reverberation time</i>) in this equation... Why 1.2? Because that's based on the SANS standards and um... on the minimum STI just from an uh... I don't know if you've seen the standard where they talk about reverb time actually a New Zealand standard that we use in South Africa because we don't have a SANS standard for reverb... So for a speech based, typically in an educational facility, it'll be between 1 and 1.2. The less the better because the lower you go the higher the speech intelligibility will be.”
International acoustic norms	Participant 2 Line 83-88 “Okay, national standards for reverberation times don't quite exist um... so only we refer to actually Australian standards. Australian, New Zealand standard okay, in fact, ah... no not this document... and because of lack of reverberation standards, it's actually incorporated into our South African Green Building standards as well.” Line 98-100 “So, education spaces we are trying to get to a maximum of 0.8, but this is already actually this is based on British standard ISO1.1.14. But the Australian standard actually it is lower well lower as in lower reverberation time...” Line 116-117 “...so this is a teaching space for primary school and secondary school 0.4, 0.5, (<i>Referring to reverberation time</i>

in seconds) okay.”

Participant 5

Line 248-260 “...1.2 (*reverberation time*) in this equation... Why 1.2? Because that's based on the SANS standards and um... on the minimum STI just from an uh... I don't know if you've seen the standard where they talk about reverb time actually a New Zealand standard that we use in South Africa because we don't have a SANS standard for reverb... So for a speech based, typically in an educational facility, it'll be between 1 and 1.2. The less the better because the lower you go the higher the speech intelligibility will be.”

Line 264-265 “...I can actually quickly get a reference for a primary school from a standard perspective which we obviously want to look at... Primary schools – this would be the unoccupied ambient noise level and this would be... 0.4 to 0.5 um... and... so it's obviously much less than that (*than what the participant originally thought RT norm is*).”

Line 273-274 “...this note actually even mentions that... Learners with difficulties with learning should have even lower reverb times than we saw”

Participant 10

Line 248-250 “... norms globally for reverb time is 0.4 or 0.5 seconds so that's a whole 1 second more which means even if you were to...”

Table 7

Personal experience.

Dominant Themes:	Excerpts from the interviews:
Ceiling treatment	Participant 1 Line 29-31 “...from my experience the most um... effective surface or boundary to add some absorption material would be the ceiling” Line 34 “...I would look at the ceiling first and then the back wall as well.” Participant 2 Line 276-279 “The only reason an acoustic ceiling would work is actually because of this void above, usually, an acoustic ceiling is hung at this say 300 or 250 below the slab so we have this big gap to extend the frequency range.” Line 284-291 “...when you look at the specifications you have to look at the testing condition the void behind makes all the difference. Okay, this is the specs of um... perforated gypsum ceiling and uh... you will see that it works differently with 200ml, 50ml, 200ml plus insulation will result in a different curve (referring to a book). Okay another example from UP (<i>University of Pretoria</i>). With this one, between 0.90 and 0.65 because of, or without the depth and with depth and insulation. So this depth is actually very important. Now if you put the same material on the wall we lose all of that.”
Clients’ willingness to pay for acoustic treatment	Participant 9 Line 142-145 “...clients are very reluctant to spend a lot of money on these things so we try to get as much bang for your buck so we try to put in the carpets, and try to choose material so that there are some absorptive qualities to it... I mean even acoustic ceilings um... it's not done it's just too expensive...”
Legacy architecture	Participant 2 Line 196-197 “Architects would consider layout and the light. But they often don't think about the acoustics.” Line 262-264 “And you know you see all these buildings in

	Sandton where they are fancy, big buildings. This is what you call, it is just legacy architecture. Architects approach buildings from outside without thinking of how people are going to do inside.” Line 442-444 “If you think about R15000 strictly speaking it's (<i>acoustic ceiling tile treatment</i>) cheaper than one screen or it's cheaper than one projector. And compared to the technology used in classrooms now well, it's the price of one computer. And that's definitely worthwhile.” Line 494-496 “(<i>referring to window design</i>)...so this is where I challenge the architects because... I find that architects are the ones that design the buildings, but quite often they don't quite understand the different ways of designing buildings to work better for people.”
Speech Intelligibility	Participant 2 Line 448-451 “Ja you see now you have to take that into the equation. But then you go back to STI of 0.3 and 0.4 and with this scenario is like, you're only hearing 30% of what is being said by the teacher. Many people don't see that when I point this out, then say my G-d they can only understand 30% no wonder they become mischievous.”
Acoustic treatment	Participant 4 Line 71-77 “So I think maybe for this classroom I'll do it in in sort of two phases if you will. There's treatment of the space or speech transmission in terms of internal acoustic quality and then I'll look at possible options of improving the sound insulation of the shell. But from a low-cost perspective the sound insulation of the shell is a very difficult thing to do with very little money. It requires changing structural elements, it requires replacing doors and that can be very much an expensive thing so... so I'll start with um... internal acoustics for me is the easy one.” Participant 5 Line 220-226 “And what I've seen in a lot of classrooms is that uh the teachers actually cover up these back walls with posters, and stuff because they always want to showcase something to make the class more relevant I suppose um... because I have seen some classrooms with this kind of band (<i>acoustic panels</i>

on back wall) but it being covered up in posters which then... Defeats the purpose of this band.”

Participant 6

Line 140-147 “And normally, I must say we ja say 95% of our work is the planning and the construction there and normally if there is like snagging or something we go into the classrooms and speak to the teacher and we've actually had one now where it was actually a refurb of a building and we had to like go back and start interacting with the teachers a bit more. But I think with acoustics is one of the actually the most important thing that needs to be addressed in the classroom and I think where you going is quite awesome if there can be minimum standards that everyone has to adhere to it would actually help um... I mean our kids as well...”

Line 183-186 “We actually don't have... we need to employ someone to get a norm or actually after it's been built to do the study. And we usually only do that if it's like an auditorium or something, we recently did that and tested the sound and then I mean you go out and you treat the back wall and you treat everything and ja.”

Participant 7

Line 18-21 “So one of the things that I didn't think would make a huge difference did make a big difference was curtains. So low cost it's not ideal it's not perfect but it does make a bit of a difference. They were getting I think 1.2 seconds reverb time and we got it down with carpet and curtains we got it down to 0.6 seconds.”

Participant 10

Line 330-332 “one... add absorption two... create diffusion and three would be limit sound generation so like adding a carpet, or vinyl floor, or rubber feet. And then additional things like replace the fan and so on...”

Table 8

Speech intelligibility.

Dominant Themes:	Excerpts from the interviews:
The effects of poor acoustics on speech intelligibility	Participant 1 Line 284-294 “the reverb reaches the learners' ears after the direct sound and you basically have like repetitions of the same sound reaching the learners' ears over a matter of um... 1-2 seconds alright. And because of that your reverb actually destroys the intelligibility of what the teacher is saying alright. So by means of absorbing these reflections, or the reverb we are actually decreasing the level of reverb and therefore sort of increasing or the difference between your direct sound and the reverb sound is getting bigger or the reverb is getting smaller, which means that your direct sound is more clearer and more understandable so therefore what the teacher is saying becomes um... more understandable or more intelligible... So, therefore, your SNR will improve in that sense. “ Participant 2 Line 156-159 “So basically we should be achieving 0.8 as a good quality okay. And a standard classroom is about 0.3 to 0.4 and this roughly very roughly translates to academics will not equate like that but it's actually ballpark you can say you're only hearing between 30 to 40% of what has been spoken.” Participant 4 Line 20-21 “Looking at it my biggest issue here would be the ambient noise level because that's immediately going to affect speech intelligibility.” Line 193-197 “...there are all these other factors, temperature, um... background noise, all of this stuff, but from an acoustics perspective um... if we get that STI right and we get the ambient noise level right and that's setting the foundation for a good teaching environment because you know to be frank, and maybe I am biased because this is what I do and what I love, but it really is the fundamental of education is communication.”

	Line 213-214 "...we just changed the ceiling we would see a definite improvement in reverberation time and in, we'd see an improvement in speech transmission." Line 221-222 "But the direct energy (<i>sound from outside</i>) will, and that will affect speech transmission so we might not see the improvement we want in speech transmission." Line 313-316 "Even with the... you know with a private school that did have a lot of money um... you know we might use a Class A ceiling and have the back wall treatment. And that should be more than sufficient to have a good teaching environment with an acceptable STI." Participant 5 Line 65-68 "...obviously the same thing with the lower ambient noise level if you can get this down obviously the speech intelligibility will be higher...but that's obviously an issue in a budget constraint in a school environment, especially on these weak points." Line 327-329 "STI is directly related to RT... So the less RT is the higher STI is. Participant 10 Line 128-129 "... So this enhances speech clarity which is part of the acoustics... so I know you're talking about reducing reverberation time and ambient noise levels adding more absorption into the room will always do that."
Effects of poor speech intelligibility on behaviour and listening experience	Participant 2 Line 145-148 "And the naughty kids sit here (<i>pointing to the back row of the classroom</i>). I need to explain why the naughty kids sit here. Because not by choice, in a traditional classroom where there is no treatment at all the speech intelligibility index in a standard classroom is about 0.3 – 0.4 at best." Line 162-164 "And if you're sitting here and you're only hearing 30% or only understanding 30% of what's been spoken in front you can get bored so quickly that's why you start becoming

naughty and doing your own thing.”

Line 168-169 “And that's why it's so important to bring this figure of 0.8 (STI) minimum so at least the kids can hear at least 80% of what has been said.”

Participant 4

Line 166-174 “Ideally more than 0.8 STI... 0.7 would be good as a rating, and 0.8 and above is excellent. I wouldn't have anything less than 0.7, in practical terms that means that about 70% of what is being said is actually being heard and your brain is filling in the rest... anything that is less than 0.7 and I think um... you know maybe, getting a little philosophical here, you know you start working too hard on filling in the gaps and you losing focus on what's actually being taught.”

Line 177-190 “...with classroom environments as they are um... you know it's already a difficult environment you've got a lot of and I'm talking about an occupied classroom now, you know you have kids talking, and especially within the state schooling systems you've got a lot of children in a classroom, um... and as soon as you start to lose that focus you know... you're finished and you know from my personal experience, it would mean falling asleep... but it's not ideal, and especially at a fundamental level, it's your primary school and high school.”

Participant 7

Line 143-145 “And STI... what's it 8x7 you should be fine in terms of STI your... you... you'll find that yes it will get quieter at the back and it will become a little more difficult to listen from the back but in such a small space it shouldn't make that much of a difference.”

Participant 10

Line 116-118 “Fans, definitely to change those because of the noise... Any kid or adult at the height of their focus power would actually struggle to tone that out.”

Line 172-177 “So speech clarity and it can be measured in STI or C50 um... it basically shows, and you might have an

	interesting view on this from an audiology perspective sound that you here in the first 50ms of a speech signal is helpful, it reiterates or almost confirms the message if it's after the first 50ms it becomes an echo or it fraises the clarity of it... so this is all working for the after the 50ms echo and reducing the amount of energy”
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