USING A SMART NOISE REGULATOR TO MITIGATE LEARNERS' POOR PERFORMANCE IN GRADE 10 MATHEMATICS CLASSROOMS

by

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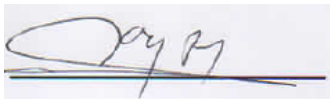
DECLARATION

I declare that the thesis *Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classrooms* is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at the Unisa for another qualification or any higher education institution.



Date: 8th of July 2021

Mr F Hagoramagara

DEDICATION

This work is dedicated to my God given parents:

In honour to my father Nehemie Barasokoroza, for being a pillar of strength to the family, and

In a memory of my beloved mother Donatille Niyonzima, for her unselfish love and her exceptional wisdom that kept the family together.

I am grateful to my parents for giving me a name that shaped my personality.

First, to my mother who chose the Swahili name Bora-Uzima at birth, and then when I started primary school the name was translated by my father in Kirundi as “Hagoramagara”.

I am very grateful for my mother’s encouragement to always rely on Jehovah and to always complete what I have started.

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ABSTRACT

This study was both a development and an evaluation study whose aim was to design a Smart Noise Regulator (SNR) technological device and assess its potential in monitoring extraneous noise in mathematics classrooms, with a view of increasing efficiency of teacher control of classroom learning environments. Learners' classroom noise has been identified to impact on their mathematical performance. Using a technological device, named the Smart Noise Regulator (SNR), this study aimed to mitigate learners' poor performance in Grade 10 mathematics. The SNR device, which was developed in this study, was designed to generate a signal to learners when their noise level exceeded an appropriate level in each phase of a mathematics lesson. The study explored five main variables associated with learners' poor performance in mathematics, namely, classroom noise level, inappropriate classroom behaviour, extraneous cognitive load (ECL), learners' motivation to engage in the lesson, and teaching and learning time. The SNR device was largely infused into a series of single experimental research designs using a multiple-baseline and A-B-A-B designs for three successive years.

Study participants consisted of 205 learners and their six mathematics teachers. Six Grade 10 mathematics classes were sampled from a population of 30 schools and two stages of cluster sampling were used. The participating group was drawn from three clusters, each of which had a different environmental noise sources identified as follows: ten schools were closest to the railway line, ten schools were within the inner-city proximity, and ten schools had the oldest school buildings assumed to be possibly subjected to noise from loose decaying building structures. Data related to the noise level were captured using the sound level meter with a computer software and the lesson observation instruction guideline. Data sought to determine numbers and types of mathematics errors that the learners made in three type of tests administered to them in the classroom that was controlled by SNR device, with the noise level range of 50 to 60 dBA and the classroom without the SNR device with the noise level ranging from 70 to 80 dBA.

The analysis of the combined data from six schools revealed that the use of SNR device in a mathematics lesson had resulted in an average of 4,8% reduction of classroom noise. Learners' accuracy in responding to algebraic tasks, Euclidean geometry and basic and mental calculations increased by 23% when the SNR device was used. Incorrect answers decreased by 16% when the SNR device was used. About 22.3% of learners' responses indicated that a noise-infested environment of 70 to 80 dBA seemed to imposed relatively undesirable constraints to effective learning when compared with a noise environment of 50 to 60 dBA when the SNR device was used.

KEYWORDS

Grade 10 mathematics

Smart Noise Regulator

Classroom noise level

Extraneous cognitive load

Academic performance in mathematics

Johannesburg metropolitan

Teaching and learning time

Mitigating classroom noise

SNR device

Traffic light colours

Learners' disruptive behaviour.

ACRONYMS AND INITIALISMS

4IR	Fourth Industrial Revolution
ALT	Academic Learning Time
AC	Alternative Current
ANA	Annual National Assessment
ANOVA	Analysis of Variance
ANSI	American National Standards Institute
ASHA	American Speech-Language-Hearing Association
BCE	Before Common Era
CDE	Centre for Development and Enterprise
DBE	Department of Basic Education
DC	Direct Current
DECA	Department of Environmental and Cultural Affairs
ECL	Extraneous Cognitive Load
EEA	European Environmental Agency
EPA	Environment Protection Authority
GDE	Gauteng Department of Education
GPA	Grade Point Average
OSHA	Occupational Health Safety Act
PCK	Pedagogical Content Knowledge
RCL	Representative Council of Learners
RT	Reverberation Time
SABS:	South African Bureau of Standards
SLM	Sound Level Meter
SNR	Smart Noise Regulator
USA	United States of America
WHO	World Health Organisation

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CHAPTER ONE
INTRODUCTION TO THE STUDY

1.1 CONTEXTUAL BACKGROUND OF THE STUDY

Learners' performance in mathematics continues to be an area of concern in South Africa. This is despite numerous educational initiatives by the government to improve the classroom learning environment and promote safety in schools. Educational trends show that mathematics performance of South African learners decreases as they progress to the next grade level (Centre for Development and Enterprise [CDE], 2013). Similar trends have been observed in the report of the Annual National Assessment (ANA[1]) of 2014 for Grades 1, 2, 3, 4, 5, 6 and 9 (Department of Basic Education [DBE], 2014). According to the DBE (2014), the performance levels in mathematics for the mentioned grade levels in 2014 were 68.4%, 61.8%, 55.4%, 37.3%, 37.3%, 43.0%, and 10.8%, respectively. Moreover, only 3% of Grade 9 South African learners were able to achieve 50% and higher in mathematics in the 2014 ANA examinations (DBE, 2014). The worst performing schools were among those with overcrowded classrooms (Marais, 2016) in which learners' levels of classroom noise would be more likely to be high. In a reaction to the report, the Ministry of Basic Education decided to review certain aspects of the classroom environment where mathematics teaching and learning traditionally occurred. Kunene (2011, p. 56) acknowledged that psychological and physical factors influence the classroom learning environment.

Some of the studies in South Africa have prioritised the development of teachers' mathematical pedagogical content knowledge (PCK) over paying attention to aspects of learning environments that are needed to facilitate the effective use of PCK (see, Hill, Rowan & Ball, 2005; Hurrell, 2013; Ijeh, 2013; Makina, 2013). While developing teachers' PCK in mathematics is important to elevate learners' mathematics performance, learner

1. Annual National Assessment (ANA) was used in South African education from 2011 to 2014 as a standardized diagnostic tool. ANA was used as a national diagnostic instrument to asses and detect learner problems in English and mathematics. The ANA tests revealed the gapes in learners' mathematics knowledges that need to be addressed (DBE, 2015).

characteristics and instructional environments could influence effective articulations of PCK in the classroom (Akey, 2006; Organisation for Economic Co-operation and Development [OECD], 2004). While the focus is on the lack of teacher training programmes and on teachers' qualifications and PCK, the improvement of the classroom learning environment for mathematics is seemingly overlooked. The CDE (2014) identified the following teaching environmental factors as influencing learners' mathematics performance: early coverage of the syllabus, learners' accumulative deficit, minimal classroom engagement, lack of motivation, inappropriate behaviour, learners' classroom noise, insufficient learning time, and teachers' stress. These factors were identified as influencing learners' mathematics performance to a greater extent than teacher qualifications (CDE, 2014). Similar findings have emerged from international studies (Fisher, 2011; Hannah, 2013; Ngware, Ciera, Musyoka & Oketck, 2015; Ofsted, 2014; Singh, Granville & Dika, 2002). Given this background, the researcher argues that mathematical content knowledge and PCK may not be solely linked to learners' poor performance in mathematics while other contextual factors are ignored.

Several studies have documented the link between classroom noise and learners' scholastic performance. Other researchers have identified learners' inappropriate behaviour and classroom noise during mathematics lessons as influencing mathematical performance (see, Hagoramagara, 2015; Langley, 2008; Ofsted, 2014; Woolner & Hall, 2010). Zhang (2015) found that about 40% of learners in urban schools were bothered by ambient noise. Zhang (2015) noted that the mathematics test scores of learners who are bothered by noise eventually dropped by 10%. In OECD (2004, p.214-2015), the 2003 PISA reported that 36% of learners mentioned that learners' 'noise and disorder' are the most frequent disciplinary problems during every mathematics lesson. Also, PISA (2003) reported that 15% of students could not perform well in mathematics lessons because of noise disruption (OECD, 2004). Classroom noise seems to be influencing some variables that are closely associated to learners' performance in mathematics (Higgins, Hall, Wall, Woolner & McCaughey, 2005; Woolner, Hall, Higgins, McCaughey & Wall, 2007).

Firstly, learner noise relates to the extent of learners' disruptive behaviour in the classroom (Arbuckle & Little, 2004; Ghazi, Shahzada, Tariq & Khan, 2013; Jacobson, 2013). Learners' disruptive behaviour in the classroom has been linked to poor performance in mathematics. Hagoramagara (2015) found that forms of disruptive behaviour during a mathematics lesson could include being talkative, creating a loud noise, participating in non-productive jokes or anecdotes, and engaging in aimless movements in the classroom. Hagoramagara (2015) further noted that learners' disruptive behaviour was problematic because it generates noise that hinders productive mathematics learning. Participants attributed 52.9% of their poor performance in mathematics to forms of disruptive classroom behaviour (Hagoramagara, 2015). The results showed that 49% of inappropriate classroom behaviour during a mathematics lesson involved elements of learners' excessive noise-making (Hagoramagara, 2015). The study corroborated findings from similar studies that investigated the influence of classroom environment on learners' scholastic performance (see, Ofsted, 2014; Robarts, 2014; Sun & Shek, 2012). Sun and Shek (2012) noted that some of the prevalent types of learners' misbehaviour in mathematics classrooms include learners' talkativeness, casual talk, chattering or simply creating noise during a mathematics lesson.

Secondly, classroom noise is connected to lack of learners' productive engagement in the classroom. Learners' engagement while learning mathematics is an area of interest among researchers (Akey, 2006; Gunuc, 2014; Salum & Shahrill, 2014; Kong, Wong & Lam, 2003). These researchers found that learners' improved performance in mathematics correlated positively to their engagement during the lesson. Gunuc (2014) documented that increased learner engagement during a mathematics lesson improved attention span and focus on what is learnt. Learner engagement promotes meaningful learning and may motivate learners to engage in higher-level thinking, which is crucial when learning mathematics (Gunuc, 2014).

Thirdly, classroom noise is connected to the loss of teaching and learning time. Effective time for teaching and learning has been associated with learners' scholastic achievement (Gettinger & Seibert, 2002). Some studies have developed models to explain the negative

influence of learners' noise on mathematical performance (see; Hagoramagara, 2015; Langley, 2008; Ofsted, 2014).

Goodman (1990) explored Caroll's (1963) model of learning and time on-task, which states that learning is a function of time. The amount of time one sets aside to study promotes knowledge assimilation (Goodman, 1990, p. 13). The Curriculum and Assessment Policy Statement (CAPS) documents, generated by DBE policy makers, allocate more time to learner-teacher interaction in mathematics classrooms than they do to other subjects therefore adhering to Caroll's (1963) model of learning. However, mathematics teachers struggle continuously to complete the syllabus owing to loss of teaching time. This is caused by many factors, including inappropriate learner behaviour and types of undesirable or inappropriate forms of noise in mathematics classrooms.

Fourthly, classroom noise is seemingly associated with elevating extraneous cognitive load (ECL). Cognitive load is "the amount of mental activities imposed on the limited working memory" (Uggen & Kauchak, 2013, p. 217) that turns to inhibit effective learning. Increased levels of cognitive load do not promote productive learning. Woolfork (2013, p. 293) illustrated the effects of learners' disruptive noise in terms of cognitive load. Plass, Moreno and Brunken (2010, p. 65) noted that learning environments with high levels of noise may overburden the limited capacity of the working memory, therefore, generating a non-productive cognitive load for learning. Zekveld, Kramer and Festen (2011) and Woolfork (2013) alluded that learners' disruptive noise in the classroom increases learners' extraneous cognitive load (ECL), which causes learning disruption and reduction in learning concentration, particularly in mathematics. Takir (2011) stated that the reduction of the ECL in mathematics bears higher relevance than in other learning areas because of the high element of interactivity and cognitive demands of mathematics.

Schunk (2008) and Schenck (2011) discussed the harmful nature of disruptive noise to learning. Furthermore, Schenck (2011) stated that learners' disruptive classroom noise may impede the assimilation of new information into sensory memory, and that learners' disruptive classroom noise may overload the limited space of the working memory.

Schunk (2008) also stated that learners' disruptive classroom noise may cause poor storage and retrieval of mathematical information in the long-term memory. Some studies have noted that the complexities of mathematics may create cognitive load and overwhelm the limited capacity of the working memory (see, Dhlamini, 2012; Mangipudy, 2010; Sweller, 2010). According to Rönnberg (2014), a noisy mathematics classroom exerts more ECL onto the working memory, which is already suppressed by the complexities of mathematics.

Finally, inappropriate classroom noise is often associated with a poor well-being of both teachers and learners. Some studies on reverberation times (RT) have explored the effect of noise and poor acoustical conditions on teachers' well-being (, see, Olokooba, Ibrahim & Abdulraheem-Mustapha, 2010; Shield & Dockrell, 2003). Kristiansen, Lund, Nielsen, Person, and Shibuya (2011) found that school teachers who were exposed to high RT and noise experienced increased levels of constant fatigue after work and resulting job dissatisfaction. Goines and Hagler (2007) and Enmarker and Boman (2004) found that both teachers and learners experienced stress symptoms consisting of tiredness, irritation, tenseness without obvious reason, headaches, concentration problems, and sleeping problems relating to noise annoyance. Seetha, Karmegam, Ismail, Sapuan and Tamil Moli (2008) noted that learners' classroom noise was the main cause of stress experienced by teachers. Learners' classroom noise not only affected teachers' mood and health, but also resulted in job dissatisfaction (Seetha et al., 2008).

A study on the effects of classroom noise on teachers found that learners' classroom noise ranged from a minimum 52dBA to a maximum peak of 86dBA (Martins Tavares, Neto & Fioravanti, 2007). Other studies revealed that teachers experienced psychological harm and develop noise-induced hearing loss when they were exposed to constant or intermittent noise at 85dB during at least eight hours of work a day (Seetha et al., 2008). The current research investigated types of undesirable noises and appropriate noise levels in mathematics classrooms. This study was largely motivated by the following observations, drawn from studies discussed in preceding sections:

- prevalence of learners' poor performance in mathematics;

- learners' disruptive behaviour during mathematics lessons;
- teachers' inability to complete the mathematics syllabus due to loss of teaching time;
- learners' off-task behaviour in mathematics due to noise level; and
- effects of ECL owing to uncontrolled noise levels in the classroom.

There is a paucity of studies and lack of development of technical innovative devices to assist teachers to regulate learners' noise in classrooms to mitigate the effects of noise on mathematical learning. The current study aimed to improve the learning environment of mathematics classrooms by developing the Smart Noise level Regulator (SNR) device to regulate learners' noise in the classroom to enhance mathematical learning (see, Section 1.10.1). The SNR was intended to regulate learners' classroom noise perceived to bear on their poor performance in mathematics. The SNR is capable of controlling learners' noise levels in the classroom to optimise mathematics instructional time, therefore, generating and preserving a desirable mathematics learning environment (see, Section 3.2).

1.2 PROBLEM STATEMENT

The industrialised era of the 20th and 21st century has stimulated an increase in noise pollution (Goines & Hagler, 2007). The increase of noise pollution and its effects on human health have moved the scientists and researchers to invest their resources in finding solutions. In addition, international organisations have developed instruments to measure noise levels to set the standards and guidelines on noise pollution [American National Standards Institutes (ANSI), 2010; American Speech- Language Hearing Association (ASHA), 2005; Berglund, Lindvall & Schwela, 1999; Occupational Safety and Health Administration (OSHA), 2016; South African Bureau of Standards (SABS), 1996]. In different countries, these standards have helped to facilitate the process of developing policies and bylaws relating to public health in major cities [Atmaca, Peker & Altin, 2005; Environmental Protection Authority (EPA), 2013; Ko, 1981; Moela, 2010]. Possibilities of increased noise pollution are imminent as the world prepares for the fourth industrial revolution (4IR), hence alternative initiatives must be sought to mitigate the destructive role of classroom noise to productive teaching and learning.

Research has demonstrated that learners' classroom noise does not only generate a negative effect on learners' performance, but that it also influences some variables responsible for poor performance in mathematics, namely, disruptive behaviour, classroom engagement, teaching and learning time, ECL, and teachers' and learners' well-being (Section 1.1). School policy stipulates that it is the primary responsibility of a class teacher to manage the class properly to enhance meaningful learning (South African School Act [SASA] of 1996). However, the ability of the classroom teacher to manage learners' noise in the classroom may be restricted by several factors. Teacher judgement on noise may be unreliable and distorted because people experience noise differently. An increase or decrease of 5 dBA cannot be detected by the human ear (Bruel & Kjaer, 1984). Without teacher awareness, learners' classroom noise may be out of proportion. There is a need to find scientific means to address the negative influence of classroom noise on mathematics teaching and learning.

Prior to this study, the researcher taught mathematics in South African classrooms since 1998. During this period, the researcher observed learners' problematic behaviour in mathematics classrooms, particularly in overcrowded classrooms. It was the researcher's observation that most of learners' uncontrolled classroom behaviour escalated into educationally undesirable noise, therefore, threatening a positive classroom atmosphere of teaching and learning mathematics. A preceding study determined the extent to which learners' classroom behaviour affected mathematical performance (Hagoramagara, 2015). The study found that teachers and learners identified classroom noise as the most troublesome behaviour that hampered productive learning in mathematics classrooms (Hagoramagara, 2015). Furthermore, the study participants emphasised that learners largely contributed to classroom noise during mathematics lessons (Hagoramagara, 2015). There is therefore a need to pay specific attention to the role of learners' classroom noise on their scholastic performance, particularly in mathematics classrooms.

Having been intrigued by the findings of the Hagoramagara (2015) study, the researcher advocated for a solution-finding initiative to mitigate the undesirable influence of noise

levels in the classroom to enhance productive teaching and learning of mathematics. The current study embarked on an intervention research design developing the SNR (Sections 1.10.1& 3.2). The educational effectiveness of the SNR was trialed through a series of single experimental research designs using a multiple-baseline and A-B-A-B designs largely employed in Grade 10 mathematics classrooms. During this trial, the principal role of SNR was to regulate learners' classroom noise, and related noise variables; and subsequently, to document scientifically, the observed effect of SNR incorporated lessons on learners' mathematical performance.

Recently studies have explored the influence of noise on learners in a school setting (see, Chan, Li, Ma, Yiu & McPheson, 2015; Golmohammadi, Ghorbani, Mahjub, Daneshmehr, 2010; Kristiansen et al., 2011; Lundquist, Holmberg, Burström & Landström, 2003; Mendel et al., 2003; Mohan & Rajagopal, 2010; Sato & Bradley, 2008; Shield & Dockrell, 2004; Zannin & Zwirtes, 2009). These studies found that noise pollution in a school setting hindered quality learning, particularly in mathematics. According to ANSI/ ASA S12.60-2010 guidelines, meaningful learning may take place in the classroom if the noise level is between 35 dBA and 85 dBA, while reverberation noise should be 0.6s, and noise ratio above 15 dBA. Some studies have focused primarily on the school's architectural plan or acoustic classroom planning. Servilha and Delatti (2014) have emphasised that the type of noise that exerts more negative effects on learning is internal classroom noise produced by learners.

1.3 THE RATIONALE OF THE STUDY

Effective classroom management has been linked with improved mathematics performance (see, Kunene, 2011, p. 49; Sowell, 2013). With an increase of noise pollution in the 21st century, the effects of noisy classroom environments are becoming an issue in classroom management (Goines & Hagler, 2007). Overcrowded classrooms have worsened the problem of learners' classroom noise in South African schools (Marais, 2016). Studies show that teachers' abilities to manage learners' noise in mathematics classrooms may be hampered by the nature and complexity of noise, teachers' perceptions of noise and learners' characteristics (Bruel & Kjaer, 1984; Guidini, Bertoncello, Zanchetta & Dragone, 2012; Seetha et al., 2008). Recent studies seem to suggest that learners' characteristics and noise-regulated learning environments are associated with improved learner performance in mathematics (Arends, 2013; CDE, 2014; Glewwe, Hanushek, Humpage & Ravina, 2011).

Efforts to reduce noise in schools seem to focus on architectural planning and acoustical insulation, which block external noise to penetrate the classroom (Section 2.1 & Table 1.1). However, efforts to block the penetration of external noise to the classroom do not seem to solve the classroom internal noise caused by learners during mathematics lessons. Local researchers are expressing concerns on the learning environment in mathematics classrooms and are looking for more innovative and cost-effective methods to generate a good learning environment and regulate learners' noise in these settings (Hagoramagara, 2015; Van Tonder et al., 2015). Some innovative devices such as Yacker Tracker, SoundEar II and Bouncing Ball have been developed to control noise in different educational settings (Bulunuz, Ovalı, Çıkrıkçı & Mutlu, 2017; Christidou, Dimitriou, Papadopoulou & Grammenos, 2015 & Van Tonder, *et al.*, 2015). Van Tonder et al. (2015) conducted an experimental study in South Africa on the effect of visual feedback on classroom noise level with two groups of Grades 1 and 2 learners. The study used SoundEar II with Light-emitting diode LED light of green, yellow and red that illuminates to give appropriate feedback to the response of learners' classroom noise. The study found that visual noise feedback by the SoundEar II feedback provided a significant reduction of classroom noise level (Van Tonder, et al., 2015).

Innovative computer applications that use a smart board to indicate noise level in the classroom have been developed. One limitation of the available devices and computer applications is their inability to give warning signals at different stages and activities of a mathematics lesson. A mathematics lesson may be divided into different activities in which different timing may be allocated to enhance meaningful learning (Grouws, Tarr, Sears & Ross, 2015, see, also Section 2.6). Learners in each activity may experience learning at different noise levels. For instance, individual classwork may require a low noise level, while louder noise may be associated with group work learning. Therefore, a consensus gap remains in terms of studies that agree to effective means and methods to regulate learners' classroom noise to enhance productive teaching and learning of mathematics. In this regard, the need to conduct this study was justifiable.

1.4 THE SIGNIFICANCE OF THE STUDY

The study may be important to mathematics teachers, to schools' heads of mathematics departments, to school principals and to policy makers in the mathematics education environment. Moreover, the study may provide solutions to mathematics education concerns, such as undesirable learners' classroom noise, learners' engagement and learners' cognitive process of doing mathematics. The SNR device was intended to regulate learners' inappropriate behaviour relating to classroom noise. It was the researcher's view that the current study would have the following benefits:

- The reduction of noise in mathematics classroom may generate a stimulating learning environment and enhance the physical and psychological well-being of both teachers and learners;
- The aspect of efficient pacing of different activities of mathematics lessons embedded in the SNR tool may motivate learners to preserve their on-task activity, thus optimising teaching and learning time;
- The special features of the SNR device and their possible influence in learning, may stimulate interest for future research in mathematics education; and
- The conducive teaching and learning environments possibly generated by the SNR tool may renew teachers' advocacy of learner-centred teaching methods in

mathematics lessons.

1.5 STUDY AIM

The primary aim of this research was to use the SNR device in improving the mathematics performance of Grade 10 learners by mitigating factors possibly associated with the classroom excessive noise level. These factors have been identified in the literature as contributing to learners' poor performance in mathematics.

1.6 STUDY OBJECTIVES

The study objectives are set as follows:

1.6.1 To determine the standard sequencing and pacing of different lesson activities during a Grade 10 mathematics instruction time;

1.6.2 To identify and measure the levels of learners' noise during Grade 10 mathematics lessons in selected schools;

1.6.3 To incorporate into the SNR device the appropriate noise levels, the timing and different activities appropriate for Grade 10 mathematics lessons; and

1.6.4 To use the SNR to monitor classroom noise levels during Grade 10 mathematics lessons, while observing its influence on learners' performance in different topics of mathematics.

1.7 STUDY DEMARCATION

The study was conducted in Johannesburg secondary schools in Gauteng Province, South Africa.

1.8 RESEARCH QUESTIONS

The study consists of the main research question and related sub-research questions.

1.8.1 The main research question

The main research question of the study is:

- Does the use of a SNR device to control learners' undesirable noise in the classrooms increase their performance in mathematics?

1.8.2 The sub-research questions

The following related sub-research questions were posed to respond to the main research question of the study:

1. Does the SNR device reduce learners' noise level in mathematics classrooms?
2. Does SNR device increase the productive use of teaching and learning time during mathematics lessons?
3. What types of learners' inappropriate classroom behaviour may be reduced by the SNR device?
4. Does the SNR device increase learners' accurate answers in mathematics?
5. Does the SNR device reduce learners' ECL emanating from the excessive classroom noise level?
6. Does the SNR device increase learners' motivation to engage effectively in mathematics problem solving tasks?

1.9 RESEARCH HYPOTHESIS

As part of the research methodology, the study used an alternative hypothesis [H_1] and the null hypothesis [H_0] to guide the scientific investigation to answer the main research question and related three sub-research questions.

1.9.1 Hypothesis one

To answer the research question, "*Does the SNR influence learners' accuracy in mathematics?*", the following alternative hypothesis [H_1] and the null hypothesis [H_0] were put up.

- **H_1:** The use of the SNR device during a mathematics lesson increases learners' accurate answers in mathematics.

- **H_0:** The use of the SNR device during a mathematics lesson does not increase learners' accurate answers in mathematics.

1.9.2 Hypothesis two

To answer the research question, "*Does the SNR influence learners' ECL emanating from the excessive classroom noise level?*", the following alternative hypothesis [H_1] and the null hypothesis [H_0] were used to guide the investigation.

- **H_1:** The use of the SNR device during a mathematics lesson reduces learners' ECL in mathematics.

- **H_0:** The use of the SNR device during a mathematics lesson does not reduce learners' ECL in mathematics.

1.9.3 Hypothesis three

To answer the research question, "*Does the SNR increase learners' motivation to engage in mathematics classrooms*?", the following alternative hypothesis [H_1] and the null hypothesis [H_0] were set up.

- **H_1:** The use of the SNR device during a mathematics lesson increases learners' motivation to engage on the task.

- **H_0:** The use of the SNR device during a mathematics lesson does not increase learners' motivation to engage on the task.

1.9.4 The main hypothesis

To answer the main research question, "*Does the use of a SNR device to control learners' undesirable noise in the classrooms increase their performance in mathematics*?", the following alternative hypothesis [H_1] and the null hypothesis [H_0] were set up.

- **H_1:** The use of the SNR device during a mathematics lesson enhances learners' performance in mathematics.

- **H_0:** The use of the SNR device during a mathematics lesson does not enhance learners' performance in mathematics.

1.10 CONCEPTUAL AND OPERATIONAL DEFINITIONS OF TERMS

The following are the conceptual and operational definitions of terms used in the study.

1.10.1 Smart Noise Level Regulator (*SNR)*

In the current study, the SNR refers to a technological device developed by the researcher to regulate learners' noise and other noise variables related to learners' performance during mathematics lessons. The main features of the SNR are adopted from the "Yacker Tracker" (see, Section 4.4.2), which is a noise regulator instrument. The "Yacker Tracker" is a product of Attention-Getter Inc. (AGI) in the United States of America (USA). As the name suggests, the "Attention-Getter" aims to grab or capture the attention of the group and get them to focus. In the same vein, this study aims to grab the attention of learners and getting them to focus mainly on learning mathematics. The development of SNR device combines various functions of gadgets: sound level meter, the timer and the displays of the traffic light model (red, yellow, and green). The SNR device is mainly powered through an alternating current (AC) but may also use direct current (DC) in an event of emergency or power outage (Section 3.2).

1.10.2 Noise

According to Mulholland and Attenborough (1981), noise is unwanted. Human beings as recipients of sound may judge between the appropriate and inappropriate forms of noise. Dasarathy (2015) describes noise as an unwanted sound disrupting one's quality of life. A sound may become undesirable when it disturbs natural activities such as working, sleeping or conversation. Olokooba et al. (2010) noted that people experience noise differently. What is pleasant to some ears may be extremely unpleasant to others depending on several psychological factors (Olokooba et al., 2010). Hence, Savale (2014)

summarised the definition of the word “noise” from the latin word “nausea” as the wrong sound in the wrong place at the wrong time (Savale, 2014, p.1). The current study sought to determine the level and sound types that are tolerable and conducive to support learning in mathematics classrooms. For instance, what is an appropriate noise level during group work may not be appropriate for individual work. This study identified three forms of noise: white noise, classroom background noise, and learners’ noise in mathematics classroom. In this study, only a noise level produced by Grade 10 learners during mathematics lessons was studied and controlled using the SNR device.

1.10.3 The teaching and learning time

Huyvaert (1998, p. 154) defines teaching and learning time in the context of classroom learning as the amount of time a learner spends engaging on a task that produces few learner-errors and is directly related to defined content area. Hagoramagara (2015) stated the matric formula of teaching and learning time, as coined by Carroll’s 1963 model of learning, as:

Teaching and learning time = **f** (allocated time, engaged rate, error rate, task relevance)

This formula shows that there are four variables necessary to achieve ATL, namely: (1) allocated time; (2) learner engagement; (3) error rate; and, (4) task. The current study determines the enhancement of the teaching and learning time by counting the number of times that learners timely and successfully completed their task on the set time in a normal classroom noise in relation to the controlled classroom noise environment.

1.10.4 Inappropriate classroom behaviour: Disruptive behaviour

Disruptive behaviour hinders the attainment of the meaningful learning of mathematics because learners distract themselves, their classmates and the teacher. Hagoramagara (2015) found that forms of learners’ disruptive behaviour in mathematics classroom manifest in three forms. Firstly, learners’ disruptive behaviour makes it difficult to hear the teacher and be attentive to what is learnt. Secondly,

learners' disruptive behaviour interrupts the sequence of reasoning during teacher-learner interaction in the classroom, therefore, making it difficult for learners to follow the teacher's explanations during the lesson. Thirdly, learners' disruptive behaviour interferes with learners' thought process during classwork exercises (Hagoramagara, 2015). Learners' inappropriate behaviour results mostly from noise levels caused by a disruptive learner or by learner's reaction to noise disruption. OECD (2004, p. 214 - 215) reported that, learners frequently spend more than five minutes, in every mathematics lesson, waiting for the teacher to quiten down the class. Learners in the PISA 2003 report alluded to the after-effect of noise in their mathematics classrooms; learners do not start working for a long time after the lessons have began (OECD 2004). The current study documented learners' inappropriate behaviour through classroom observations determining the noise types and their frequency in the mathematics classroom. During the study, the noise associated with disruptive behaviour was measured as classroom sound pressure (dBA).

1.10.5 Inappropriate classroom behaviour: Engagement behaviour

Engagement is defined by Bellanca (2015) as the result of a teacher's use of specific strategies and programmes to keep learners' attention on the material or content under study. Webber, Krylow and Zang (2013) highlight the results of a national survey on learner engagement and found that a higher level of engagement significantly contributed to cumulative grade point average (GPA), and higher learner satisfaction academically. The current study observed the influence of the SNR device on learner engagement through lesson observations, through mathematics achievement tests given to learners in different topics in mathematics.

1.11 OUTLINE OF THE DISSERTATION

This dissertation is divided into six chapters.

Chapter One provides an overview theoretical and contextual background of the study.

Chapter Two reviews the literature in relation to types of classroom noise, and the effects of noise types on learning mathematics. The conceptual framework of the study is also explored in this chapter. Furthermore, the process of intervention research followed in this study is outlined.

Chapter Three provides an extensive discussion of the technical development of the SNR device. Data used to determine the acceptable noise levels at different stages of a mathematics lesson are presented and discussed. The chapter also provides a discussion of the general features of SNR, its functionality and operations in regulating learners' noise in mathematics classrooms.

Chapter Four presents the research methodology of the study, reflecting on the selection of study participants. The chapter provides a discussion of the instrumentation process inherent to the study. Methods of data collection and analysis are explained. The chapter closes with a pertinent discussion on ethical issues.

Chapter Five sets out the findings and the emanating results.

Chapter Six summarises the findings of the study. Recommendations are made and prospects of the utility of the SNR to influence future educational research are outlined.

CHAPTER TWO
LITERATURE REVIEW

2.1 INTRODUCTION

New technology has mostly been associated with an increased noise level in the environment. For instance, Milne (1979) pointed out the invention of the wheels era prior to the common era (BCE). Emperor Julius Caesar considered imposing a daylight ban on cart and chariot racing because of the noise of the chariot wheels (Milne, 1979). By the middle ages, loud noise that an average person could experience included thunder and earthquakes, African drums, church or temple bells and the occasionally awful uproar of battle (Hendy, 2013).

In the modern age, the situation has been changed by the rush of industries, machinery, new communication networks, and scientific advances. Hendy (2013) refers to the 20th and 21st centuries as the 'noise amplified age' and states that the conquering engines and the rise of the machines of the first three industrial revolutions have consistently increased the level and rate of noise recurrence in the environment. At the same time, scientific discoveries during the 20th and 21st century have increased humans' understanding of sound properties, thus enabling humans to measure and study the effects of noise on humans. Efforts were made to reduce the effect of noise levels on the workplace. Also, several organisations were set up to regulate and to control noise level. Examples of these include the United States Environmental Protection Agency (EPA) and (European Environmental Agency (EEA).

Different countries have set up registrations for noise control. In South Africa, for example, there is the Noise Control Regulations Act No. 73 of 1989 and in the USA, there is the Noise Control Act of 1972. Understanding reverberation and noise ratio coefficient of building materials improved architectural acoustics (Neuman, Wrobleski, Hajicek & Rubinstein, 2010). Even though there has been advancement in the use of the technology

in classroom teaching, there is still a lack of technological advances to control learners' noise in a critical subject like mathematics. Therefore, it is worth drawing from the literature to increase our knowledge on the topic of noise and to find the ways of developing technological devices to control learners' noise in the mathematics classroom.

The first section of the literature review discusses noise measurement, the different types and sources of noise, and the effects of noise on learners in mathematics lessons. The second section reviews a collection of books, theses and journals related to learners' noise during mathematics teaching practice and its relationship with the main variables of the study. These variables are disruptive behaviour, learner off-task behaviour and motivation, teaching and learning time, cognitive load, teacher and learner wellness. The third section discusses literature related to the conceptual framework of the study. Thereafter, the research design framework of the study is discussed.

2.2 NOISE MEASUREMENT

Sound pressure is transmitted by means of millions of colliding molecules of air (Milne 1979, p. 57). Mulholland and Attenborough (1981) pointed out that the sound pressure carries the energy as they travel through the air. Furthermore, these authors identified the flow rate of the energy as the sound power (Mulholland & Attenborough, 1981, p. 10). Milne (1979, p. 57) noticed that the sound power encountered in everyday life was extremely wide. For example, the noise of a jet aircraft is 10^{13} times as intense as that of a whisper with $10^{3}$of sound power (Milne,1979, p. 57).

For practical purposes, the sound power (psi) is logarithmically converted into dB units using the formula: $dB = 10\log\left[\frac{p}{p_0}\right]^2$ or $dB = 20\log\left[\frac{p}{p_0}\right]$, where

p is a weighted sound pressure, while

p_0 = 20 µPa or 0, 00002 Pa is reference sound pressure (the threshold of human hearing).

The advantage of converting from sound pressure units to dB units is that the big range of 0 to 10 000 000 psi units of sound pressure can be read from the threshold of hearing to the threshold of pain (0 to 140dB). Table 2.1 shows the conversion of the sound power into (dB) with samples of sound sources familiar to humans. It also shows the noise level relative to human health and the subjective impression noise level as sensed by an average human ear.

Table 2.1: Sound pressure (Pa) to sound intensity level (dB)

Effects on Human Health	Sound intensity Factor (pressure in Pa)	Subjective Impression on humans	Sound intensity level in (dB)	Source
	10^{14}		140	Jet engine 25m away
	10^{13}	Painful	130	Rivet gun
	10^{12}		120	Jet take off 50 m away
	10^{11}	Deafening	110	Rock drill
	10^{10}		100	Popular music group
	10^{9}	Very loud	90	Street with heavy trucks
	10^{8}		80	Busy street with cars
	10^{7}	Loud	70	Maximum of conversational speech
	10^{6}		60	Ordinary conversation
	10^{5}	Moderate	50	Low conversation
	10^{4}		40	Soft music
	10^{3}	Faint	30	Whisper 1m away
	10^{2}		20	Quiet town dwelling
	10^{1}	Very faint	10	Rusting leaf
	1		0	Threshold of hearing

(Milne, 1979)

The implication of a logarithmic conversion of sound pressure kPa into dB is that small changes in decibel value can cause a tremendous change in the intensity of noise. In addition, a drop of 3dB means that the noise level is cut to half its previous level (Milne 1979, p. 58). It is worth noting how dB measurement behaves when sound power (source) is doubled, particularly as this study involves many learners in one classroom. Mulholland and Attenborough (1981, p. 15) explain that even though a single motorcycle may create 100 dB at a kerbside, it does not mean that two motorcycles will create 200 dB. The result of adding two identical sound levels together suggests an increase of 3 dB, meaning that two motorcycles will generate 103 dB, four motorcycles 106 dB, eight motorcycles 109 dB, and so on (Mulholland & Attenborough, 1981, p.15).

In a classroom setting with many learners it is important to detect, measure and control noise sources. According to Adetunji and Olorunfemi (2014) and Fidêncio, Moret and Jacob (2014), noise sources are identified and divided under two major divisions, namely, internal and external. The next section discusses noise sources and the effects on learning mathematics.

2.3 INTERNAL CLASSROOM NOISE

According to Adetunji and Olorunfemi (2014) and Fidêncio, *et al*. (2014), internal noise is mostly generated through human activities. These activities may include verbal discussion in the classroom, occasional dragging of furniture on the floor, movement of learners and teachers in and out of the classroom, noise from ceiling fans and air condition systems, noise from occasional knocking and opening of doors, and intercoms (Adetunji & Olorunfemi, 2014).

Adetunji and Olorunfemi (2014) also list sources of internal classroom noise. These authors' research revealed that some aspects of internal noises are necessary for learning. For instance, without teacher learner interaction or learner-to-learner interaction, only minimum learning will take place. Adetunji and Olorunfemi (2014) further mention that while momentarily noise, such as a knock on the door, can be ignored, constant noise emanating from electrical installations in the classroom must be switched off or repaired

if faulty. The noise source that seems to be problematic in the classroom is the noise generated by learners. Types of learners' noise may be linked to different factors including the age and gender of learners, and the level seniority of the teachers in charge of the lesson.

Shield, Greenland and Dockrell (2010) conducted a study in 140 classrooms focusing on factors that influence learners' noise in the classrooms. The study revealed that more occupied classrooms were noisier than the less occupied classrooms (Shield *et al.*, 2010). The same findings resonate with those of Mendel *et al.* (2009) who conducted their study in 14 kindergarten classrooms, and Kristiansen *et al.* (2011) who conducted their study in ten secondary schools. The noise level increased as the number of learners increased in the classroom. As previously discussed, this may be explained as followed: when an identical sound level is doubled, it increases the noise level dB by multiples of 3 dB (Mulholland & Attenborough, 1981, p. 15). This finding may be used to explain why many South African schools known for overcrowded classrooms are much noisier. The researcher argues that if a device can be developed to influence the noise in most classrooms, the noise level will be reduced as a whole, even that of overcrowded South African classrooms.

Kristiansen *et al.,* (2011), Sato and Bradley, (2008), Shield *et al.* (2010) echo that when learners are given a difficult task to perform, the internal classroom noise increases. Conversely, when learners are given low cognitive level activities, the noise level remains constant. Mathematics is known to exert a high level of cognitive demand on learners, and this finding may be the reason why mathematics lessons might have a higher level of noise than other learning areas. The current study explored these claims in the South African learning context. Another classroom noise (internal noise), which combines learners' factors and the quality of the classroom structure is known as reverberation noise.

2.3.1 Reverberation noise in the classroom

According to Adetunji (2010), a reverberation may be perceived when the reflected sound reaches the ear in less than 0.1 second after the original sound. A short reverberation time is good for speech intelligibility and the longer the reverberation is timed, the poorer the speech intelligibility. Different studies in mathematics classrooms have highlighted the negative effects of reverberation time on learners' memory. For instance, Kristiansen *et al.'s* (2011) study found that school teachers exposed to high reverberation times and noise experienced increased levels of stress, tiredness, constant fatigue after work, and job dissatisfaction.

According to research by the ANSI (ANSI S12.60-2010 ANSI) on the classroom acoustics ANSI standard, the acceptable level of reverberation time in the unoccupied classroom must not exceed 0,6 seconds in smaller classrooms or 0,7 in larger classrooms. To minimise reverberation times, the architectural acoustics recommend that classroom building material should be of a lower noise to ratio coefficient so that the noise can be absorbed or defused without creating an echo in the classroom. Table 2.2 sets out the signal to noise ratio building material coefficient (α).

Table 2.2: Absorption coefficient of common material at several frequencies

Material	Frequency in Hertz					
	125	**250**	**500**	**1000**	**2000**	**4000**
Concrete	0,01	0,01	0,02	0,02	0,02	0,03
Plaster board	0,20	0,15	0,10	0,08	0,04	0,02
Acoustic board	0,25	0,45	0,80	0,90	0,90	0,90
Curtains	0,05	0,12	0,25	0,35	0,40	0,45

(Milne, 1979)

The current study does not provide a solution for reverberation noise, but simply recommends features and building material for mathematics classrooms. The next section discusses the effects of external noise in the classroom.

2.4 EXTERNAL CLASSROOM NOISE

According to Adetunji and Olorunfemi (2014) and Fidêncio, *et al*. (2014), major causes of external noise may include the following:

- background noise from humans, such as learner and teacher conversations and activities, as they move around the surroundings of the classroom building;
- movement of vehicles;
- hooting from car parking areas, noise from activities from neighbouring buildings (for example generators etc.); and
- noise from climate features such as noise caused by rainfall, wind, thunder; and
- noise from an external air conditioner.

Mohan and Rajagopal (2010) conducted a study in 120 classrooms and found that the external noise of the classroom had a significant effect on background noise in unoccupied classrooms with opened windows. This might suggest that in some cases the common sense of blocking off the outside noise (by closing doors and windows) may minimise the effects of external noise to learners inside the classroom.

Minimising the effects of external noise by blocking it off may be all that is needed. In line with this, Golmohammadi *et al.,* (2010) found that outdoor noise did not significantly affect indoor noise level. In addition, Lundquist *et al.* (2003) found that external noise had a negligible effect on learners who are inside the classroom. Zannin and Zwirtes (2009) cautioned that schools, and particularly classrooms' positioning may be contributing factors to increased background noise in classrooms. For example, Zannin and Zwirtes (2009) found that classrooms built within close proximity to schoolyards and sports courts, experienced increased background noise. Golmohammadi *et al*. (2010) also explored the factor of noise per learners' gender and found that the effects of external noise on background noise in boys' schools were significantly greater than that in girls' schools. The next section discusses background noise and its effects on intelligibility.

2.4.1 Background noise and intelligibility

According to the Noise Control Regulation by the DECA (1998) in South Africa, background noise is also known as ambient noise. This is clearly defined as “the noise level taken by the sound level meter at a measuring point in the absence of any alleged disturbing noise at the end of a total period of at least ten minutes after such a meter was put into operation” (DECA, 1998, p.1). In South Africa, noise control regulations recommend the ambient noise level of 40 dBA for educational facilities (Act No. 73 of 1989). As for the ANSI (ANSI /ASA S12.60-2010) on the classroom acoustics, it is stated that background noise should not exceed the level of 35dBA in an unoccupied classroom. Guidini *et al.* (2012) pointed out that some studies set classroom ambient noise between 40 dBA and 45 dBA (Guidini *et al.,* 2012). Since South Africa’s noise regulations set background noise at 40 dBA and neither at 35 dBA as in USA, nor at an extreme 45 dBA, the impression is created that South Africa takes a moderate approach to classroom noise. In a classroom, a low level of the background noise is required for better speech intelligibility, particularly over a longer distance (Milne, 1979).

According to Guidini *et al.* (2012), the presence of learners in the classroom increases a background noise of 5 dBA to 10 dBA. This may also suggest that a 40 dBA in an unoccupied classroom will measure 45 dBA to 50 dBA in the presence of the learners. This may cause poor speech intelligibility, or the teacher might have to raise his or her voice to a level higher than normal. Table 2.3 shows the background sound level in dBA and the maximum distance for speech intelligibility in metres.

Table 2.3: Sound level for speech intelligibility

Background sound level (dBA)	Maximum distance for intelligibility (metres)
48	7
53	4
58	2.2
63	1.2
68	0.7
73	0.4
77	0.2
82	0.13
87	0.07

(Milne, 1979)

In South Africa, the distance of most classrooms exceeds ten metres in length, suggesting that the background noise with learners in the classroom must be below 45 dBA to enable learners sitting at the back of the classroom to hear the teacher clearly. In the current study, the background noise in mathematics classrooms is determined by measuring empty classrooms and by measuring the average minimum noise level during the lesson.

2.4.2 White noise and music in learning mathematics

White noise, also known as thermal noise, is referred to as noise that is static, with an equal energy per unit wavelength (Pettai, 1984, p. 40-41). White noise has a constant, uniform energy distribution of noise in term of frequency (ibid). Mulholland and Attenborough (1981) explained that when a sound consists of several separate waves with some forms of harmonic relationship between them, such a sensation is called “music” (p. 10). However, when sound waves produce a chaotic sound, or random signals such as those coming from a boiling kettle or waterfall, it is called white noise. Söderlund, Sinkström, Loftesness, and Sonuga-Barka (2010) found that white noise improved the performance of learners with ADHD and of those who are naturally inattentive. However, it was also found that white noise worsened the performance of attentive learners. Mulholland and Attenborough (1981, p. 10) pointed out that music can also be described as noise if it is loud in intensity or undesirable to humans.

A number of researchers are exploring ways to incorporate music classroom mathematics teaching, particularly in primary school (Viladot, Hilton, Casals & Welch, 2017; Bryce, 2016; Dobrucki, Kin & Kruk, 2013; An, Tillman, Boren & Wang, 2014). Studies that explore ways to incorporate music in teaching mathematics suggest that musical sensation with harmonic sounds may be used to bring about learning environment that motivate and stimulate learners' recall. Studies that incorporate music in teaching mathematics use the music the rhyming or mnemonic that repeats mathematical number patterns or reminding the learners of a particular concept in mathematics.

Therefore, in the current study, music was used instead of the other types of noise, whenever there was a necessity to increase the noise level in Grade 10 mathematics classroom to account for the effectiveness of the SNR device (see, Section 4.4.5). The use of the music instead of other types of noise enabled the researcher to proceed the study within the parameters of appropriate research ethics. As pointed out by Pathaka, Sheteb and Bhandroric (2015) and Prasher (2000), noise pollution has detrimental effects on humans: it interferes with the communication, cause sleeplessness and reduce efficiency, and may affect cognitive development and functions related to the long-term memory. Noise pollution may also have extreme effects, causing deafness, cardiovascular and mental breakdown. Johnson and Christensen (2012, p.115) admonish researchers who conduct their studies in education to make sure that participants are protected from mental and physical harm.

Harshitha and Siddiqua (2017) conducted a study on the prevalence and effect of earphone usage among adolescents and found that 60% of the participants use the earphones for music on a daily basis. Given the prevalence of the learners who used earphones and who listened to the music, the use of the music in the current research provided the researcher with an opportunity to test the common hypothesis that sensations of music maybe conducive to a better understanding of mathematics.

2.5 THE EFFECTS OF LEARNERS' NOISE IN MATHEMATICS CLASSROOM

ANSI (ANSI /ASA S12.60-2010) on classroom acoustics reported that in the USA, thousands of learners across all states were unable to understand 25% to 30% of what was said in their classroom because of excessive noise and reverberation in the classroom which interfered with their ability to hear their teachers clearly. Guidini *et al.* (2012) also noted that the mere presence of learners in the classroom increased the noise in the classroom, regardless of whether they were noisy or silent. According to Guidini *et al.* (2012), there is a significant correlation between the teacher's voice intensity and classroom environmental noise during teaching time.

The intensity of the teacher's voice varied from 52 dBA to 68 dBA. This reached a level of 7.48 dBA above the environmental noise, which was still below the standard signal to noise ratio (see, Section 2.4.1 & Table 2.3). A good signal to noise ratio (S/NR) should not be less than +15 dB, that is, the signal strength should be at least 15 decibels above the background noise level to achieve good speech intelligibility by the listener. Therefore, signal to noise ratio is the most suitable measurement to determine whether the teacher's voice is audible to all learners in the classroom regardless of the position of the teacher and learners. Guidini *et al.* (2012) found competitiveness between learners' classroom noise and the teacher's voice. Therefore, the higher the noise in the classroom, the louder and higher pitched the teacher's voice became (Guidini *et al.,* 2012). According to Sun and Shek (2012), learners' disruptive behaviour, including elements of learners' classroom noise, remains a thorny issue for teachers. Sun and Shek (2012) found that this type of learners' misbehaviour in lower academic performance.

2.5.1 Effects of learners' noise on their engagement in mathematics

According to Chapman and Vagle (2011, p. 12-15), lack of motivation by learners creates a different aspect of inappropriate behaviour, which emits an undesirable noise in learning. Learners who are not motivated may appear to be daydreaming in the classroom, displaying the *I don't care* attitude. Such learners act largely as entertaining clowns in the classroom and during lessons. Chapman and Vagle (2011, p. 14) also noted that unmotivated learners who act as classroom clowns tended to disrupt the progress of

the class by offering funny commentary, and by making silly gestures and sounds to amuse the classmates. This behaviour may happen because a learner is bored, struggles to sit attentively or is misunderstanding the subject content (Chapman & Vagle, 2011, p. 14).

In South Africa, inappropriate behaviour caused by learners' off-task behaviour and lack of motivation in mathematics classrooms seems to be aggravated by the manner in which these learners socialise, their phobia and longstanding misconceptions they may be experiencing when learning mathematics (Vandeyar, 2014).

2.5.2 Effects of learners' noise on the teaching and learning time in mathematics

In the 1920s Julia Barnett, who was the physician, studied the effects of noise on teaching time. The study aimed to determine the efficiency in teaching when noise was present in a school setting. The results showed that teaching time was reduced by 25% whenever it was noisy outside the classroom (Hendy, 2013).

Noise in the classroom has also been found to be disruptive to the teacher and other learners (Seetha *et al.,* 2008). When a learner is talking to other learners or speaks out without the teacher's permission, it makes it difficult for fellow learners and the teacher to concentrate (Arbuckle & Little, 2004). In a modern mathematics education setting, teachers must encourage learners' participation by guiding them with a set of provoking and probing questions. Troublesome and uncooperative learners may monopolise teaching time by acting as the derailed clowns in the classroom, frequently asking irrelevant questions, arguing with the teacher, or unproductively dominating classroom discussion.

2.5.3 Effects of learners' noise on the ECL

Woolfork (2013, p. 228) and Slavin (2007) used the term "sensory memory" to illustrate that the body senses play a crucial role during the initial phase of the learning process. Furthermore, Woolfork (2013) stated that sensory memory involves stimuli from the environment, which involves the main body senses of sight, hearing, touch, smell, and

taste to transmit information to the brain. Therefore, divided attention caused by learners' negative classroom behaviour is a major obstacle in learning mathematics. Learners' negative behaviours include being talkative, cracking jokes, coming to class late, asking irrelevant questions aimed at slowing down the flow of the lesson, and using or fiddling with their cell phones during a lesson.

In coding, Schenck (2011, p. 43) indicated that the mind generally focuses on only one item at a time while some information is being processed simultaneously in the working memory. Working memory pays attention to what seems important at a time while it subsequently blocks away other incoming stimuli. Woolfork (2013) underscored the importance of keeping information in the working memory activated with the aim of preserving it in that cognitive location. The author noted that when attention is shifted away, activation decays or fades quickly.

Schenck (2011, p. 231) noted that learning mathematics places considerable cognitive demand on working memory. This strenuous overload of working memory occurs because in mathematics three demanding tasks are being processed spontaneously by the brain. These three tasks include holding in mind the sequence of the procedure, performing the calculations or computations; and, shifting the focus to appropriate new strategies. Therefore, the importance of the limited space and fragility, and the sensitivity of the working memory cannot be overly emphasised, particularly in learning mathematics. Halin, Marsh, Hellman, Hellstöm, and Sörqvist (2014) found that learners' noise manifesting during a mathematics lesson impacted negatively on learners' working memory in coding organising, retrieving and storing acclaimed knowledge.

The effect of learners' noise on working memory when learning mathematics may be experienced when the limited space of the working memory is overloaded. This may result in the reduction of attention span and subsequently result in poor retrieval of information from the long-term memory. The impact of learners' classroom noise on long-term memory may be understood better by focusing on the main cognitive functions: remembering and forgetting, storing and retrieval of knowledge. All sort of unused ideas

could be gradually lost and forgotten (Woolfolk, 2013, p. 306). An alternative explanation for the loss of information in the long-term memory is that the neural connection, like any muscle, grows weaker over time when it is not used. In addition, neurons that are not used for a long time are likely to eventually die. In the working memory, forgetfulness is caused by a decay and interference (Woolfolk, 2013, p. 294).

Woolfolk (2013, p. 30) encourages elaborative rehearsal as a crucial means to struggle against forgetting. The brain works harder to retrieve memory related to mathematics operations than memory related to another learning area. Schenck (2011) emphasised the importance of easy access of retrievable memory from the long-term memory, pointing out that it must be accessible in order to be used when needed. In the context of this study, Woolfork (2013, p. 292) noted that ECL is the cognitive capacity that is used by learners to deal with problems that are not related to the learning task. Examples of such capacity include trying to get classmates to stop interrupting so that full concentration may be dedicated to a particular learning task.

Woolfork (2013, p. 293) has placed learners' classroom noise among factors that increases ECL. Learners' classroom noise may cause disruption and therefore reduce the concentration that is required for learning mathematics. This may result in an inappropriate processing of learning material, preventing learning and discouraging learners in the classroom. Mangipudy (2010) expressed concerns that studies on cognitive load fall short in providing a pratical advice on how to mitigate classroom noise, particurally the classroom noise that may not be contibuting to the learning of mathematics but rather a potential source of extrinsic load. The extent to which learners' noise affect learners' performance in mathematics will be determined by using a series of learners' experiments in the classroom (see, Section 4.3.3 & Section 4.4.6).

2.5.4 The effects of learners' classroom noise on the health of mathematics teachers and learners

As early as in the 1920s, the effects of the different types of noise in various educational settings caught the attention of the scientists and the academics. For example, in 1927,

the industrial psychologist Donald Laird was concerned about the effects of noise on typists' efficiency. Donald Laird compared typists' speed and the number of mistakes they made when they were switched from a quiet to a noisy environment (Donald Laird,1930). Furthermore, Donald Laird also hooked them up to the machines to calculate the rate at which they burned calories. The results were that the best typist worked about 7% faster when it was quiet. Under noisy conditions, the typists used 19% more energy on average. It may be reasonable to acknowledge that noise affects workers' health and work productivity (Hendy, 2013, p. 306).

The negative effects of excessive noise on human health is documented by several researchers (Pathaka, Sheteb & Bhandroric, 2015; Christidoo, Dimitriou, Papadopoulou, & Grammenos, 2015; Savale, 2014; Prasher, 2000). Pathaka, Sheteb and Bhandroric (2015) and Prasher (2000) mention that beside the general effects of noise pollution which interfere with the communication, like sleeplessness and the reduction of efficiency, noise pollution may have extreme effects, causing deafness, cardiovascular and mental breakdown. In the school context, Prasher (2000) noted that noisy environments may affect the cognitive development and functions related to the long-term memory and academic success. Noise practitioners have also conducted studies that were instrumental in developing ways to measure the continuous noise level that damages hearing.

It is now possible to know the daily time that a worker can stay in a noisy working environment without being subject to sensing the damage. With workers in mind, the Table 2.4 sets out the recommended times of daily exposure to noise levels.

Table 2.4: Recommended noise limit relative to continuous time

Exposure time (per in day, in hours)	Noise in (dBA)
16	80
8	85
4	90
2	95
1	100
0.5	105
0.25	110
0.125	115

(Milne ,1979)

Noise in the working environment, particularly in an educational setting, may have additional negative effects. According to Van Petegem (2008), learners' well-being is closely perceived to be the product of a positive classroom climate. This is considered to be a major output indicator of quality education. Van Petegem (2008) found that learners' well-being and good hearing, positively correlated with their level of scholastic achievement. A study conducted by Seetha *et al.* (2008) found that classroom noise affected younger learners in secondary schools (13-15 of age) to a greater extent than for older learners. Classroom noise made learners feel moody, irritable and depressed owing to the noise level in the classroom (Seetha *et al.* 2008). The gender difference was also noted by Seetha *et al.* (2008) who found that female learners were more affected by classroom noise than male learners. In order to get the most out of classroom teaching, Seetha *et al.* (2008) observed that female learners would rather sit in the front row, very close to the teacher. In addition, Servilha and Delatti (2014) found that learners who were affected by noise constantly would continually ask noisemakers to keep quiet and insist on sitting in the front seats.

Learners are probably not the only ones affected by internal noise in the classroom. Guidini *et al.* (2012) noted that teachers who worked in noisy classrooms suffer from constant voice loss. Furthermore, Guidini *et al.* (2012) recommended that teachers and other professionals who used their voices as working tools should go through regular vocal assessments. According to Seetha *et al.* (2008), female teachers seemed to be more

affected by learners' classroom noise. Female teachers scored higher in indicating that classroom noise affected their concentration at work. They raised their voices or shouted to be heard in the classroom, hence they became more irritable to classroom noise and reacted more to learners' noise than their male counterparts (Guidini *et al.* 2012). These findings may indicate that female teachers need a more pleasant environment for teaching purposes (Seetha *et al.,* 2008). Furthermore, Seetha *et al.* (2008) found that a group of teachers aged (41-50 years) was less affected by the classroom noise.

2.6 THE TIMING AND SEQUENCING OF MATHEMATICS LESSON ACTIVITIES

Jones (2012, p. 93) discovered that majority of mathematics teachers allocate their teaching time in the following four main phases: (i) the teachers go over the previous night's homework with the learners, (ii) teachers use examples to teach new concept of the lesson, (iii) learners solve mathematics problems after the new concept explanation have been provided by teachers, and (iv) teachers provide the homework for the next day. Pacing and timing activities in mathematics lessons were found to be among the main determining factors of learners' performance in mathematics (Grouws, Tarr, Sears & Ross, 2015). According to Grouws *et al*. (2015), mathematics teachers who used integration of lesson elements achieved more by preserving more time for learners' independent work than teachers who adhered to subject specific elements. In addition, the integrated method provided learners with 43.5% of the time to explore while the subject-specific method substituted learners' time to explore with 38% of teaching (chalkboard teaching). Grouws *et al.* (2015) have demonstrated a viewpoint of integrating subject-specific lesson elements during a mathematics lesson. The significance of Grouws *et al.'s* (2015) study is its calculation of the average time that teachers used in each mathematical activity. Table 2.5 shows different methods used by mathematics teachers and the sequencing of elements included in a mathematics lesson.

Table 2.5: Grouws et al.'s (2015) sequence and elements included in a mathematics lesson

Subject-Specific Lesson Element	Description
Warm-Up	Focus on general mathematical concepts not related to the primary instructional objective of the class period.
Review	Review solutions to homework assignment.
Lesson Preview	Introduction of the instructional objective for the class period.
Teach	Presentation of new mathematical concepts.
Practice and Apply	Students work independently or collectively to solve problems related to content taught during the class period.
Assessment	A measurement of students' learning using test or a quiz.
Closure	The wrapping up of the mathematical content in a lesson that can occur in various forms at the end of a class period.
Non-Instructional	Activity not related to mathematics.

Integrated Lesson Element	Description
Warm-Up	Focus on general mathematical concepts not related to the instructional objectives of the class period.
Review	Review solutions to homework assignment.
Launch	Introduction of a context for the instructional objective for the lesson.
Explore	Presentation of new mathematical concepts.
Share and Summarize	A whole class discussion of student ideas and key mathematical ideas pertinent to the present lesson.
Apply	Students work independently or collectively to solve problems related to the lesson's objective.
Assessment	A measurement of students' learning using a test or quiz.
Closure	The wrapping up of the mathematical content in a lesson that can occur in various forms at the end of a class period.
Non-Instructional	Activity not related to mathematics.

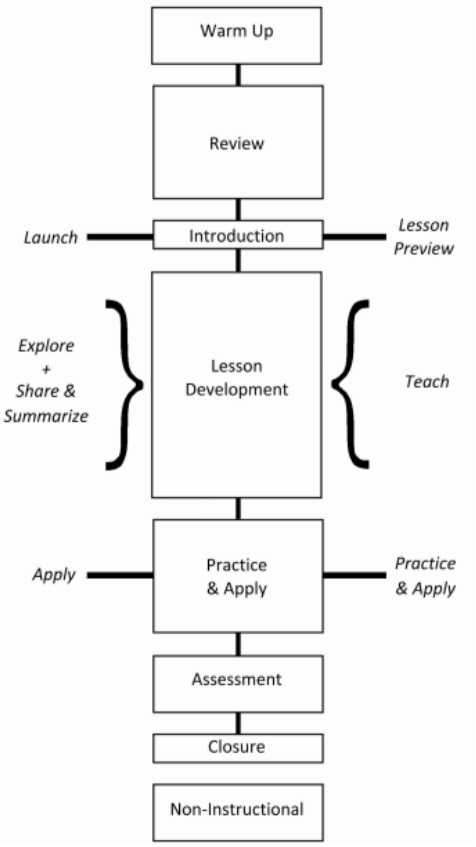


Table 2.6 provides guidelines to design a research instrument to determine the percentage of time allocated to each mathematical activity. The determined and researched ratio of time allocated to each activity in the mathematics lesson is embedded into the SNR device. Table 2.6 of Grouws *et al*. (2015) show the percentage of time allocation of different elements of a mathematics lesson that preserves more time for learners' independent work.

Table 2.6: ***Grouws et al.'s (2015) percentage time allocation of different elements of a mathematics lesson in order to preserve learning time conducted in 47 different classrooms***

Lesson elements	*Integrated Curriculum n =47*
Warm-up	*8.0*
Review	*14.6*
Launch	*2.3*
Explore	*43.5*
Share and summarise	*4.6*
Apply	*14.7*
Assess	*2.5*
Closure	*0.9*
Non-instructional	*8.9*

In developing the features of the SNR device, the researcher utilised the model of Grouws *et al.* (2015) to incorporate time allocation with different elements of the mathematics lesson into the SNR. The aim was to provide learners with more learning time, in particular, time for exploration and application. Furthermore, the SNR tool makes provision for the assessment and increased individual work.

It was the researcher's view that the SNR features and its applications in the teaching of mathematics could provide solutions to classroom problems that are related to unproductive noise (Ramaligela, 2012; Marais, 2016). Ramaligela (2012) noted that student teachers and novice teachers find it difficult to integrate the mathematical knowledge they acquired in university when teaching mathematics to high school learners. Therefore, student teachers and novice teachers particularly find it difficult to control teaching time because of learners' behavioural problems and classroom noise. In the same vein, Marais (2016) also found that student teachers failed to control learners because they were unprepared for the reality of the extreme noise they encountered in overcrowded South African classrooms. The researcher took into consideration the sequence in which majority of mathematic teachers organise their lessons (see, Jones, 2012). The SNR features may assist teachers to adhere to the sequence and timing of

the mathematics lesson. The next section discusses literature related to the noise level at each stage of the lesson.

2.6.1 Noise at different stages of a mathematics lesson

Effective mathematics learning would require the teacher's voice to be audible to all learners. In addition, the projection of the teacher's voice needs to be at the proper degree (not very low) so that learners can exert more effort to listen. The teacher's voice should not be so loud that it encourages learners to want to shut their ears to reduce the teacher's loud voice (Fidêncio, et al., 2014). Either of these extremes will generate an ECL. The relationship between sound pressure and distance conforms to the inverse distance law (1/r). Sound pressure is inversely proportional to the distance of the point of measurement from the source. This means that doubling the distance, the sound pressure is halved. The inverse distance law decrees that if a sound pressure level is 6dB, and the distance from the source is doubled, the sound pressure will decrease by 50%) of its initial value and becomes 3dBA. The inverse distance law is helpful in determining teachers' sound pressure voice, given the distance between the teacher and the sound meter.

Using a signal-to-noise ratio, inverse distance law, different studies, and local and international guidelines on noise (World Health Organisation [WHO], 2018; Chan et al.,2015; Soderback, 2009; Berglund et al., 1999; DECA, 1998), the current study determined the acceptable noise level at each stage of a mathematics lesson for the following:

- Noise emanating while learners enter the classroom;
- Noise during routine administrative classroom work;
- The level of the teacher's voice during a mathematics lesson;
- Classroom noise emanating during teacher-learner interaction;
- Classroom noise emanating during group work; and,
- Noise emanating during learners' individual work in mathematics.

2.7 CONCEPTUAL FRAMEWORK

Suter (2012, p. 89) defines a conceptual framework as a process or an initiative that connects the important elements of the problem being investigated and embeds it within a larger context. Also, Sefotho (2018, p. 31) mentions that a conceptual framework may be presented graphically, or as a narrative description of the main variables of the emerging research problem. Suter (2012, p. 89) recommends that researchers use a visual diagram showing the connection that exists between main variables of the study. In the current study, a graphic conceptual framework was developed showing the relationship between the classroom noise level and the variables influencing learners' performance in mathematics. Sefotho (2018, p. 31, 32) points out that a researcher constructs a conceptual framework from a synthesis of concepts, meaning that the variables, principles and assumptions are gleaned from several theories. A conceptual framework provides a platform for debates about the innovations within the field of study.

First, this research is framed by Walberg (1980) synthesis of major models of school of learning, which is a combination of different elements derived from the spectrum of teaching and learning theories. The researcher gleaned from the findings of Walberg's (1980) model of school of learning related to productive classroom learning environment and contextualised them in terms of the effects of learners' noise on learners' performance in mathematics. Walberg (1980) indicated that the productive classroom environmental is important for a classroom teacher to transfer quality and quantity of learning instructions to the learners. The section of Walberg's (1980) synthesis dealing with the productivity-environmental characteristics in the classroom is located on left section of the Figure 2.1.

Figure 2.1: Walberg's (1980) model of school of learning

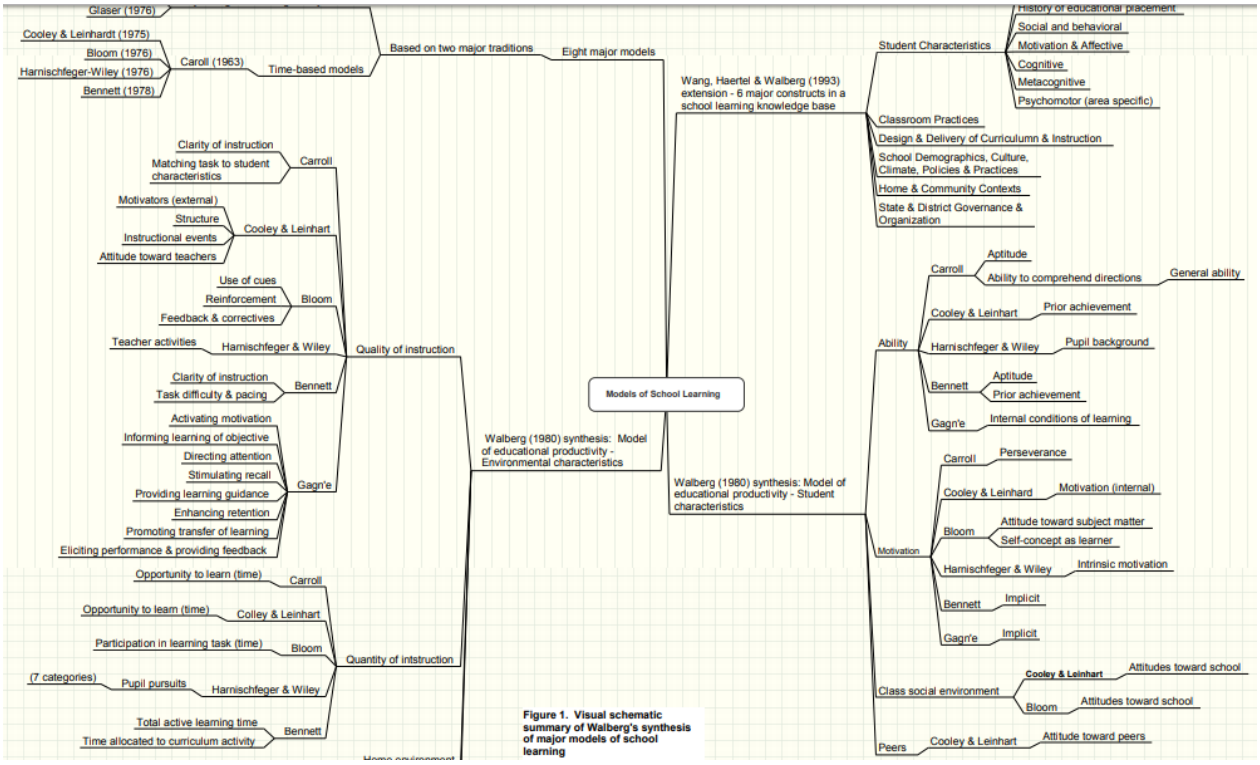


Figure 1. Visual schematic summary of Walberg's synthesis of major models of school learning

The rational of underpinning the current study in the classroom productivity-environmental characteristics section of Walberg's (1980) synthesis is motivated by the researcher assumption that the SNR device may bring about productive learning environment in Grade 10 mathematics classrooms. The section of Walberg's (1980) synthesis underpinning the current study focuses on a number of scholars whose work was to improve learning and teaching classroom environment:

- Carroll's (1963) model of school learning;
- Cooley and Leinhardt's (1975) model for investigating classroom processes;
- Bloom's (1976) human characteristics and school learning;
- Gagne's (1977) internal condition of learning; and
- Bennett's (1978) task difficulty and pacing.

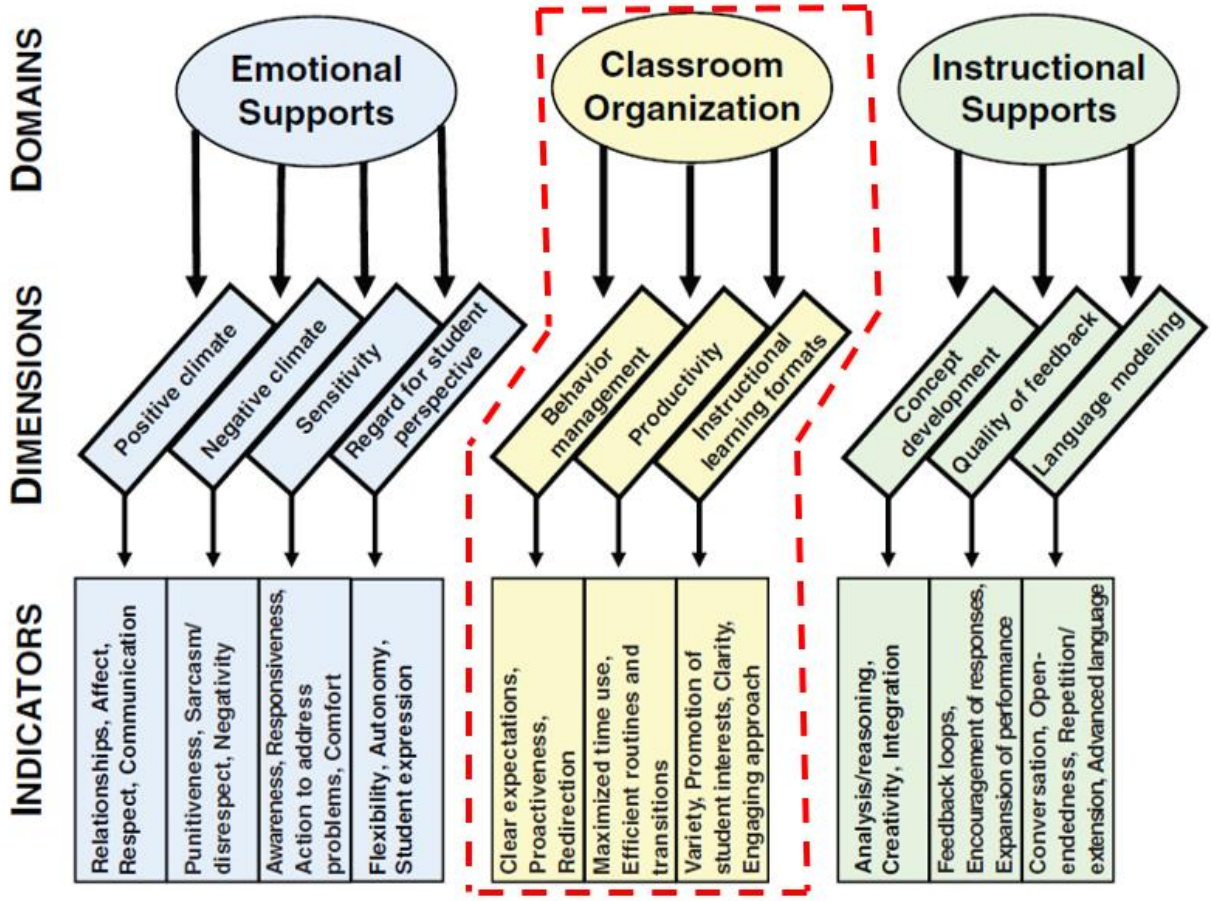
Carrol (1963) and Bennett (1978) directed their attention on the construct of clarity of instructions in the classroom as a major influential factor of classroom quality instruction. The researcher has demonstrated in the literature that inappropriate classroom noise level is a variable responsible for classroom poor speech intelligibility. In mathematics classroom, inappropriate classroom noise level reduces the clarity and quality of learning instructions that the teachers transmit to the learners (see, Section 2.4.1).

Gagne (1977) focused on the factors related to classroom environment that enables the learners to direct their attention to learning, stimulating and enhancing recall. The researcher has demonstrated in the literature a connection between excessive classroom noise level and learners' ECL, and the effects of learners' ECL on the learners' ability to pay attention in the classroom, stimulating and enhancing recall were discussed in section 2.5.3

Carrol (1963), Bloom (1976) and Bennett (1978) directed their attention on how a poor classroom environment affects learners' time to learn, the length of time that the learners remain motivated to learn, participate in the lesson and also the effect of the overall instruction time. The researcher has demonstrated in the literature a connection between excessive classroom noise level and academic learning time (ALT), learners' engagement in mathematics lessons (see, Section 2.5.1 and Section 2.5.2).

Secondly, the researcher used a section of the Classroom Assessment Scoring System (CLASS) framework to validate the constructs used in the conceptual framework of the current study. The CLASS framework is a standardised observation measure of classroom quality developed by Pianta and Hamre (Pianta, La Paro & Hamre, 2008). The CLASS framework was validated in over 3000 primary and secondary schools by a number of researchers (Pianta & Hamre, 2009). Parkarinen, Lerkkanen, Poikkeus, *et al.* (2010) agree that the CLASS framework may be generalised grobally because it has been validated in several classrooms in different settings. The CLASS assesses three domains of classroom quality: emotional support, classroom organisation and instructional support (See the CLASS framework in Figure 2.2).

Figure 2.2:The CLASS Conceptual framework for classroom (Pianta & Hamre, 2008)



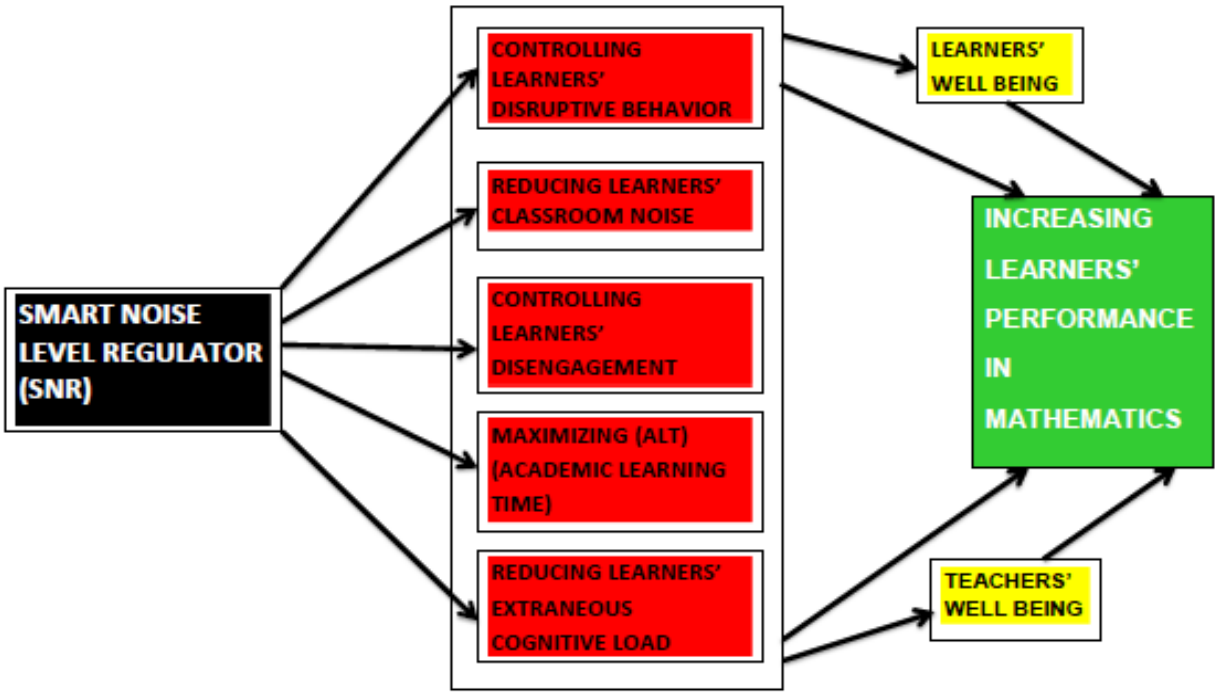
The current study focuses on the domain of the classroom organisation of the CLASS framework. The classroom organisation domain focuses in improving classroom environment in three dimensions: the management of learners' classroom behaviour, learners' classroom productivity and instructional learning formats.

The researcher positions the current study in the domain of the classroom organisation because the researcher believes that the use of SNR device in controlling learners' noise in Grade 10 mathematics classroom has a positive effect on the indicators of the CLASS three dimensions of classroom organisation. It will make it easier to manage learner's inappropriate behaviour, maintain the clarity of classroom instructions, motivate students

to be proactive, maximizing the use of learning time, and the efficient use of transitions of mathematics lesson phases.

In developing the conceptual framework, the researcher used the Walberg's (1980) model of school of learning, the CLASS framework, and different research work related to controlling background and learners' noise, learners' disruptive behaviour in the classroom, learners' off-task behaviour (see, Section 2.3 & Section 2.4). The next diagram outlines the process and the factors that formed the subjects of the study, and was controlled by the SNR device to enhance learners' performance in mathematics.

Figure 2.3 :Schematic conceptual framework of the current study



The current study developed the SNR tool (see the black block on the left of the Figure 2.3). The instrument (SNR) was intended to influence five different variables that formed the focus of this study, namely: learners' disruptive behaviour, learners' classroom noise, learners' task behaviour, the teaching and learning time, and learners' ECL (see variables depicted in red blocks in the Figure 2.3). Numerous researchers in mathematics education have found that these variables exert a ***direct*** influence on learners' performance in mathematics (see, Section 1.1).

For the purpose of the current study, the SNR device was used to:

1. Control and possibly **reduce** learners' classroom noise;
2. **Control** learners' disruptive behaviour;
3. **Enhance** learners' on-task behaviour that involves their engagement and motivation during mathematics lesson;
4. **Maximise** teaching and learning time in mathematics; and
5. **Reduce** the effects of learners' ECL on their memory during mathematics lessons.

Other education researchers have pointed to other classroom factors with an **indirect** influence on learners' performance in mathematics. These factors are depicted in the yellow block of the Figure 2.1 and include teachers' well-being (Kristiansen *et al*., 2011; Finlayson, 2009; Fisher, 2011); learners' well-being (Seetha *et al.,* 2008); and an environment that is conducive to learning (Murugan & Rajoo, 2013, Allen & Hessick, 2011).

The use the SNR tool was intended to generate a relatively better learning environment for mathematics to promote the wellbeing of teachers and learners and to reduce health factors caused by excessive noise in the mathematics classroom (see, Section 2.5.4). Therefore, the SNR tool was used to control both the outlined direct and indirect variables related to classroom noise, with the central aim of improving learners' performance in mathematics.

2.8 THE RESEARCH DESIGN FRAMEWORK

The current research used the intervention research design, also known as research-based design. According to De Vos, Strydom, Fouché and Delport (2018), the intervention research was developed in the 1980s by Thomas and Rothaman. In the intervention research, design studies are carried out for the purpose of creating and testing innovative human services approaches in order to prevent or enhance possible problems or to maintain the quality of life. According to De Vos, et al. (2018), the advantage of developing the intervention research design is that it allows the progressive empirical stages to

develop a new technology or technological device to test the device in the research field and to disseminate the findings, a process that was at the heart of the current study.

According to Anderson and Shattuck (2012), intervention research design is strongly positioned toward the building of the prototype to find a solution to an existing problem. The designed prototype undergoes continuous testing and redesigning processes in collaboration with stakeholders who would benefit from the new invention or programme. Goff and Getenet (2017) highlight the strength of intervention research design because of the involvement of the community or practitioners in the different phases of the study. These practitioners heartily embrace the invention or the programme and use it in their day-to-day practice. This practice therefore has long-term benefits on their practice and the community they serve. Therefore, McBride (2016) highlighted the benefit of the intervention research design, pointing out that it is able to bridge the gap between research and the practice.

Given the benefits of the intervention research design in practice, it would be reasonable to assume that more students who are pursuing doctoral programmes should be using this research design in their studies. However, Goff and Getenet (2017) noted that a number of doctoral students are seemingly reluctant to use this research design in their studies owing to many phases embedded in the design, the time constraint, and the challenges related to collaboration with other practitioners (Herrington, McKenney, Reeves & Oliver, 2007). Table 2.7 demonstrates six phases of intervention research design, the number of activities in each phase and how each activity should relate to the study. In fact, the last column in Table 2.8 shows how the six phases were incorporated in the current study.

Table 2.7: Process of intervention research by Rotmans and Thomas 1994 (in De Vos, Strydom, Fouché and Delport, 2018)

Phase description	Number of activities in each phase	Activities in each phase relative to the study
Phase 1 ***Problem analysis and planning***	• Identifying and involving participants	*Done at MEd study*
	• Gaining entry and cooperation from the research field	*Done at MEd study*
	• Identifying concerns of the population	*Done at MEd study*
	• Analysing the identified problems	*Done at MEd study*
	• Setting goals and objectives to solve the problem identified	*Done at MEd study*
Phase 2 ***Information gathering and synthesis***	• Using the existing information resources	*Discussed in literature review*
	• Studying natural examples	*Done at MEd study* *Discussed in literature review*
	• Identifying functional element of successful models	*Discussed in literature review*
Phase 3 ***Design***	• Designing an observational system	*Designing SNR prototype*
	• Specifying procedural elements of the intervention	*Explaining the functionality of SNR prototype*
Phase 4 ***Early development and project planning***	• Developing preliminary intervention	*Collecting data related to noise level* *Technical assembling of SNR prototype*
	• Conducting a pilot test	*Using SNR prototype in School A*
	• Applying design criteria to the preliminary intervention concept	*Adjustments of SNR prototype noise level*
Phase 5 ***Evaluation and advance development***	• Selecting an experimental design	*A number of A-B-A-B single experimental design and* *Series of classroom observations*
	• Collecting and analysing data	*Collecting and analysing data using SNR Device in School A, B and C*
	• Replicating the intervention under field conditions	*Adjustments classroom observations recording sheet and the SNR prototype noise level*
	• Refining the intervention	*Collecting and analysing data using SNR Device in school D, E and F*
Phase 6 ***Dissemination***	• Reporting the finding	
	• Recommendation of the news invention	

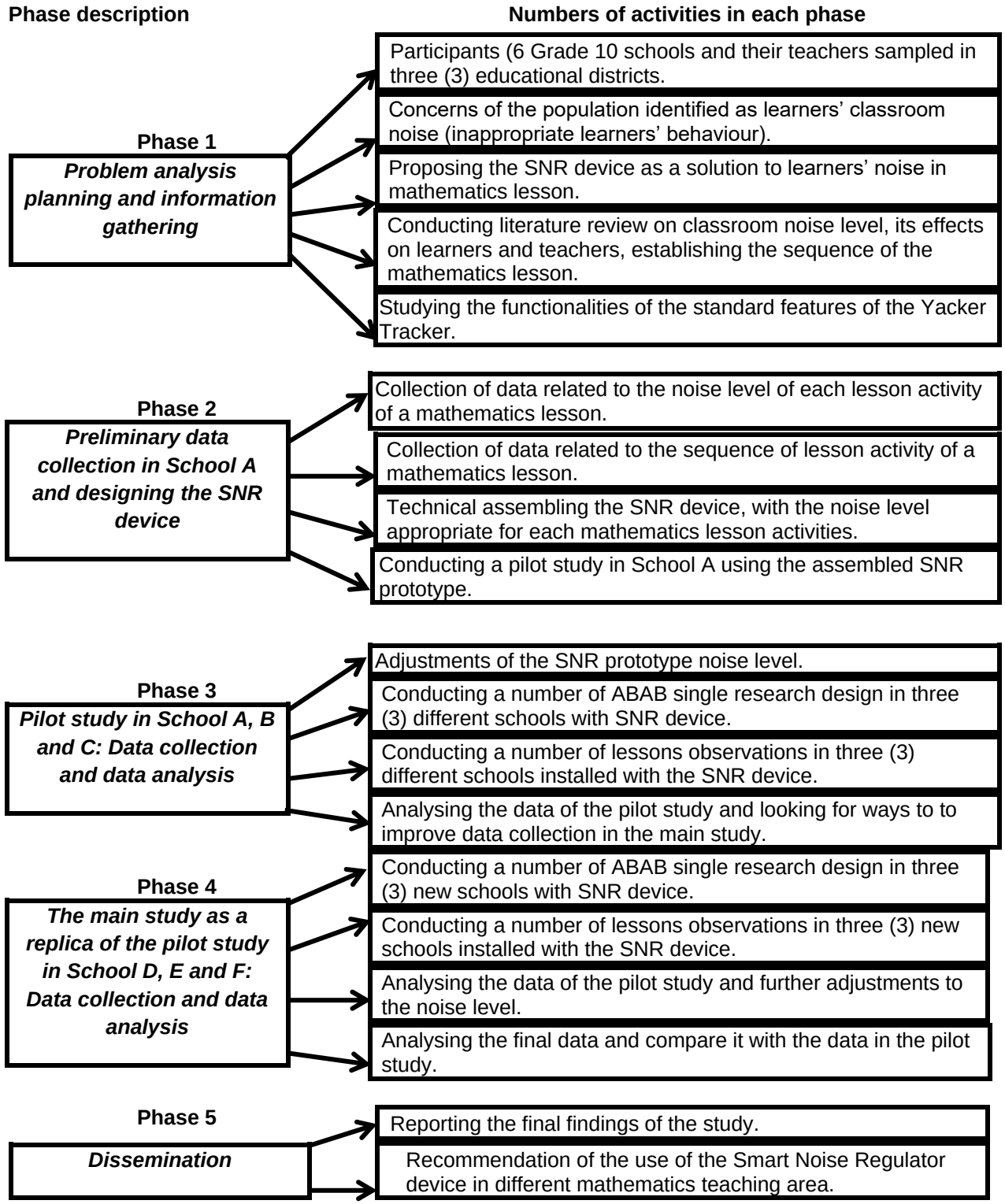
Anderson and Shattuck (2012) suggested on how to conduct an intervention research design in educational studies, and ways to combine similar phases or leave out phases that are irrelevant to the study. To minimise the cumbersome and lengthy protocols of the six phases, scholars and researchers in education are overcoming these obstacles by combining similar phases. Table 2.8 shows four phases of the intervention research design, the themes and action in each phase, as well as the activity related to the current study. The four phases are adopted from Goff and Getenet (2017) and McBride (2016).

Table 2.8: Phases of intervention research by Reeves 2006 in (Goff & Getenet, 2017 and McBride, 2016)

Phase description	Themes and actions	Activities in each phase relative to the study
Phase 1 ***Investigation of a problem of a practice and developing a proposed solution intervention***	• Contextual analysis	*Done at MEd study*
	• Background/groundwork	*Done at MEd study*
	• Formulation of research project	*Discussed in literature review*
		Designing the SNR prototype
Phase 2 ***Problem of a practice and the proposed solution to participants and participants are recruited into the project***	• Implementation of the research project	*Collecting data related to noise level* *Technical assembling of SNR prototype*
	• Data collection	*Using SNR prototype in School A*
	• On-going data analysis and refinement	*Adjustments of SNR prototype noise level*
Phase 3 ***The intervention is implemented and further refined with participants in real world context***	• Evaluation	*A number of A-B-A-B single experimental design and* *Series of classroom observations*
		Collecting and analysing data using SNR device in School A, B and C
		Adjustments classroom observations recording sheet and the SNR prototype noise level
		Collecting and analysing data using SNR device in school D, E and F
Phase 4 ***Dissemination***	• Formulation of design principles	*Reporting the findings and commendations*
	• Reporting the finding	
	• Recommendation of the news invention	

The current study opted to utilise five phases of the intervention research design. The five phases are gleaned from the four phases advocated by Goff and Getenet, (2017) and McBride (2016), and the six phases espoused by De Vos, et al. (2018, p. 476). The researcher deemed the phases applicable to the study. The rationale for using five phases instead of six was informed by the fact that at the time of conducting the current study, the researcher at the masters' level (see, Hagoramagara, 2015) had already investigated many activities inherent in the preliminary stages of the study. It was also conceived that four phases would not be ideal for the current study because the study needed to conduct many tests and to implement pilot study phases. Figure 2.6 provides a model summarising the five phases that the study used for the intervention research design.

Figure 2.4: Phases and their inherent stages of the research design framework for the current study



2.8.1 Phase 1: Problem analysis, planning and Information gathering

According to Goff and Getenet (2017), the preliminary phase is also called the development phase by McBride (2016). According to Revees (2006), this preliminary phase discusses the statement of the problem, the rationale of the study and the research questions (see, Sections 1.1 to 1.8). According to De Vos, *et al.* (2018) and McBride (2016), the first phase includes the analysis of the problem in the research field. During this phase, the participants are identified as the area of concern or an issue of importance.

The analysis of the problem was done at masters' level (see, Section 1.2 & Section 1.3). The study explored the impact the Grade 10 learners' behaviour had on their performance in mathematics. The study used a survey with interviews and questionnaires to explore the extent to which learners' inappropriate classroom behaviour affected their performance in mathematics. The participants consisted of 105 Grade 10 mathematics learners, five mathematics teachers and five mathematics Heads of Departments. Data were collected over a period of six months. The data revealed that learners attributed 52,9% of their poor performance to the inappropriate behaviour manifested by their fellow learners in the classroom. The type of learners' inappropriate behaviour that learners complained about entailed elements of excessive and noise that is not oriented towards productive learning, being overly talkative, and making noise when telling jokes and making loud noise. All of these noise types would be generated during a formal mathematics lesson, thereby inflicting a learning harm to other learners. In addition, teachers complained that they were struggling to complete the syllabus owing to the noise related to learners' inappropriate behaviour. The current research emanated from its consideration of the recommendations made in the master's study that a technological device could be utilised to control or regulate learners' noise in the mathematics classroom, thereby influencing their mathematical performance (Hagoramagara, 2015).

Since it was already conducted at masters' level, the researcher did not have to go back to the field to initiate the preliminary phase of the doctoral study (see, Hagoramagara,

2015). The current study opted to preserve similar population characteristics that had been considered in facilitating the master's study. In the master's study, the population type consisted of Grade 10 mathematics learners and their incumbent teachers. The study at master's level used a population from a single educational district. In the current study, the population was extended to Grade 10 mathematics learners and their teachers drawn from the three educational districts. The decision to use a bigger population in the current study was largely informed by the research design, which requires collaborators or participants with different methods of teaching. In addition, the literature review shows that classroom noise level may be influenced by various factors and settings, which may not be found in one educational district.

Guided by the recommendation by Goff and Getenet (2017), similar phases may be combined during the intervention research design. The current study was initiated in phase two of the intervention research design. Furthermore, De Vos, et al. (2018, p. 480-481) pointed that the literature is reviewed at the preliminary phase of the section. The literature review section explores the field of study, theories and models used. In the context of the current study, Section 2 discusses the main variables of the studies, namely *noise*, *disruptive behaviour, off-task behaviour, the teaching and learning time and ECL*. The study has considered the local education policies and other models possibly used to control noise in the classroom. Grade 10 mathematics lesson plans from the DBE have also been used to align the sequences of a mathematics lesson in the SNR device.

2.9 CONCLUSION OF THE CHAPTER

This chapter gave an overview of the factors that gradually increased environmental noise level for the past 20 centuries. The review discussed the efforts that have been made to measure the noise level aiming to mitigate the effects of increased noise level on humans' livelihood in the 20th and 21st century. The effects of learners' noise in mathematics classrooms have also been discussed. The conceptual framework has discussed the constructs that frames the study. In addition, a section of literature review outlined the intervention research phases that guided the research processes.

The next chapter discusses the second phase of the intervention research, namely, the prototype phase. It makes clear the development of the SNR; it highlights the functionalities of each of the main features; and it provides details about its possible capability in reducing learners' classroom noise at each phase or level of the lesson. All of these considerations were largely aimed at accelerating learners' performance in mathematics. In the next chapter, the focus is on phase two of the current study, which involves the assembling of the SNR prototype.

CHAPTER THREE
DEVELOPING THE SMART NOISE REGULOR PROTOTYPE

3.1 INTRODUCTION

In intervention research, the prototype phase marks the formal beginning of the research inquiry (Kennedy-Clark, 2013). Kennedy-Clark (2013) posit that a research process involves many reiterations where each one becomes a part of micro-circle of the research. De Vos, et al. (2018) indicate that the main purpose of using the intervention research design in a study is to progressively develop a programme or a new technology to the benefit of the practitioners.

Herrington, McKenney, Reeves and Oliver (2007) assert that technical aspects in developing the innovative programme or technological device may be delegated to other collaborators in the study. Therefore, the development of the features of SNR device, the programming of its noise level and the timing of each phase of the mathematics lesson were entirely the researcher's idea and innovation. However, the assembling of the electronic parts, the casing and the continuous testing of noise levels was done by the researcher in collaboration with an electronic engineer specialist who was remunerated for the service.

In this study the SNR device was installed in the mathematics classroom to assist Grade 10 learners to self-regulate the noise they emit. Section 3.2 sets out the general features of the SNR device that enabled Grade 10 mathematics learners to regulate their level of noise appropriate for each session of mathematical lesson. This section also provides a description of the technical features of the SNR device by stating the step-by-step methods that were followed in assembling the SNR device. Furthermore, this section provides a detailed discussion on the noise regulating feature of the device and the empirical data used to determine the appropriate noise level for each phase of a mathematics lesson.

3.2 THE SMART NOISE REGULATOR PROTOTYPE

The SNR has the following functionalities: The SNR has a function of measuring learners' sound pressure during different stages of a mathematics lesson. The sound pressure has been calibrated in decibel meter (dBA). The SNR has a visual feature that provides a reading of learners' level of noise in the classroom: The green light goes on when learners' noise level is at the acceptable level. In contrast, the yellow light goes on when learners' noise level is less than 10dBA above the acceptable level while the red light goes on when learners' noise level is exceeding 10dBA of the acceptable level, and the noise persists for longer than five seconds.

The SNR has a built-in timing of each phase of mathematics activities. Each phase of the lesson is aligned to an appropriately measured noise level. Table 3.1 shows five phases of a mathematics lesson, the timing of each phase, the learning activity of each phase and the programmed appropriate noise level of each phase of the SNR device.

Table 3.1: Proposed noise level of each phase of mathematics lesson

Lesson Phase	Timing of each phase	Activity during each phase of mathematics lesson	Ranges of acceptable noise level
1	5 minutes	Warm-up, review and correction of previous homework	70 – 80 dBA
2	9 minutes	Introduction of the new concept	60-70 Dba
3	13 minutes	Work examples practice and explore	70 – 80 dBA
4	10 minutes	Assessment or consolidation test	50 – 60 dBA
5	3 minutes	closure and administration	70 – 80 dBA

The SNR noise level automatically changes to the appropriate noise level as pre-programmed for each activity of the mathematics lesson. The standard features of the SNR are an emulation a traffic light colours and the timing display. These features are clearly visible to teachers, learners and to anyone entering the classroom. The standard features are designed to capture the attention of the onlookers and respond accordingly in a conventional way. For example, if the traffic light is green, yellow or red, all the onlookers in the classroom could probably respond in the same way. The researcher

anticipated that the features of the SNR device may generate a significant reduction of classroom noise, related factors and in turn increase of the learners' accurate answers in mathematics. Prior to the commencement of the study, the researcher anticipated that the SNR device may produce the desirable results based on the local and international studies that used visual colour feedback to mitigate learners' classroom noise (Bulunuz, Ovalı, Çıkrıkçı & Mutlu, 2017; Christidou, Dimitriou, Papadopoulou, Grammenos, 2015; Van Tonder, *et al.*, 2015). Van Tonder, *et al.* (2015) show that colour of the traffic light reduced learners' classroom noise significantly. Bulunuz, *et al.* (2017) also report that the learners responded to the features of the Yacker tracker and reduced their classroom noise level. The anticipated outcome of the SNR to mathematics teachers is to assist them to incorporate the main phases of the lesson and their timing, therefore, enhancing the smooth delivery of the lesson. The rationale for using them is explained in Section 3.2.1.

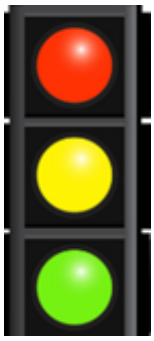
3.2.1 The conventional use of the traffic light colours

London and major cities of USA experienced an increase of horses, buggies and wagons from 1868 and these forms of transportation caused many fatal accidents (Mcshane, 1999). By the start of the 19th century, automobiles also contributed to even more road congestion. Starting from 1868, inventors looked for ways to control the traffic. By 1923, the use traffic light signals had become the most efficient method to control road traffic, which included automobiles and pedestrians (Mcshane, 1999). From then, traffic light signals used green, yellow and red. The green colour signalled safe, proceed, or clear; the yellow colour signalled to proceed with caution; and the red colour signalled stop or danger. The conventional use of traffic light colours has become public knowledge to urban dwellers and is also widely used in other disciplines, such as the food industry, work performance and general behaviour at work (Koenigstorfer, Gröppel-Klein & Kamm, 2014; Mcshane, 1999).

Koenigstorfer *et al.* (2014) pointed out that food and drink companies used the conventional colours of the traffic light to signal to the customers the amount of nutrients contained in the food and beverage in relation to danger it may cause to their health. For sugar consumption, green would signal low, meaning acceptable, yellow would signal

medium or tolerable, and red would signal high, meaning that it caused danger to health (Elliot, 2009; Koenigstorfer *et al.*, 2014). In addition, the conventional use of the traffic light colours has been used in performance monitoring. For instance, The Red Amber Green (RAG) has been used to track the project performance at the workplace (Koenigstorfer *et al.,* 2014). Red represents projects that are likely to fail while amber or yellow refers to projects that are time and resourcefully risky. Green refers to projects on target. In the current study, the conventional use of traffic light colours, namely red, green and yellow, has been adopted to convey similar messages to both learners and teachers.

Figure 3.1: Conventional traffic light colours



Green light would signal to learners that the noise level is at the acceptable perimeter noise level. In contrast, yellow light would indicate that the noise is less than 10 dBA above the acceptable noise level, therefore signalling to learners that they must reduce their noise. The red light would indicate that the noise level is exceeding 10 dBA of the acceptable level. Section 3.2.2 discusses the rationale of using the timing display feature in the SNR device. Based on the data and other studies, it also provides reasons in terms of why more time should be allocated for certain sessions or phases of a lesson.

3.2.2 The conventional use of the timing display

In Hagoramagara (2015), mathematics teachers mentioned that learners' noise from their disruptive behaviour was one of the factors that caused them to fall short in completing the syllabus. According to Hagoramagara (2015), teachers mentioned that learners may be quiet but still unproductive because of improperly timed classroom mathematics

activities. Based on this observation, the researcher noticed that pacing the activities in a mathematics classroom was of paramount importance. The researcher saw a need to include the timing of each activity of the lesson in the SNR device. It was thought that this would guide the teacher in terms of when it would be proper to make a transition to the next activity and to make learners more time conscious while they learned mathematics and other subjects. Figure 3.2 provides an example of the timing display fitted on the SNR device.

Figure 3.2: Timing display

The researcher used the percentage allocation of time as per Grouws *et al*. (2015) as a guideline (Section 2.6). Furthermore, the researcher customised and adjusted the guidelines for a 40 minutes period according to researcher's observation notes of the ideal mathematics classroom in the South African context. Table 3.2 presents information on the timing of each phase of a mathematics lesson adapted from DBE lesson plans and also validated with lessons observations.

Table 3.2: The timing and activities of a mathematics lesson

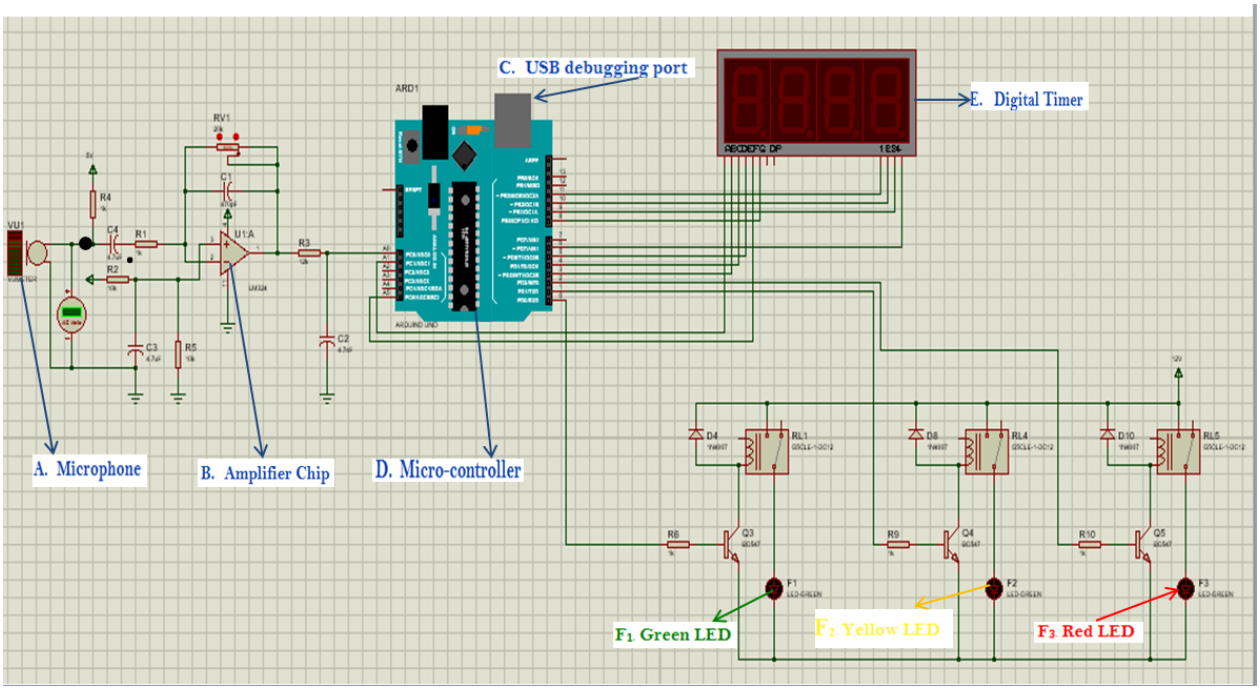
Lesson Phase	Timing of each phase	Activity during each phase of mathematics lesson
1	5 minutes	Warm-up, review and correction of previous homework
2	9 minutes	Introduction of the new concept
3	13 minutes	Work examples practice and explore
4	10 minutes	Assessment or consolidation test
5	3 minutes	closure and administration

The next section discusses the technical features of the SNR device that the researcher assembled in collaboration with the electronic engineer.

3.3 TECHNICAL FEATURES OF THE SMART NOISE REGULATOR

This section discusses the internal electronical mechanism of the SNR device that makes it possible to capture the sound in the classroom and send accurate signals to learners. First, the classroom sound generated by the classroom teacher, learners and other factors is captured by the condenser microphone (see, A microphone). The condenser microphone receives the sound power (in Pa) and converts it into an electrical signal. The amplifier chip (see, B amplifier chip) amplifies the electrical signals into the input of electrical values that can easily be interpreted. The conversion of the sound power into electrical values makes it possible for the microcontroller (see, D microcontroller) to read and interpret the electrical values that are generated. The microcontroller is programmed and coded by an electronic technician to receive the appropriate electrical signals from the amplifier and to respond according to the parameter already programmed. If the values received are above the set parameters, the microcontroller sends the signal to the red LED light and illuminates a red colour. If the values received are 5 dBA or above the desirable parameters, the microcontroller sends the signal to the yellow LED light and illuminates a yellow colour. If the values received are within the set parameters, the microcontroller sends the signal to the green LED light and illuminates a green colour. The microcontroller is programmed to display in green, yellow or red, depending on the level and the session phase of the mathematics lesson. Figure 3.3 shows the internal functionality of the SNR device.

Figure 3.3: Technical functionalities of the SNR device



The source of the information that the microcontroller uses to read and interpret electrical values and to command the appropriate actions are from the researcher's empirical data related to the researched noise data and the duration of each phase of the lesson (see, Section 5.2). To enable the data related to the timing of each phase of the mathematics lesson and the appropriate noise level to be read by the microcontroller and thereafter to execute the instructions, data were first written as a source code (see appendix code). The empirical data converted were appropriately coded using a PC and C++ programming language (Bruel & Kjaer, 2019, p.53). The empirical data were then converted into a source code that was inserted from the PC into the microcontroller by using an USB debugging port. The USB debugging port is easily accessible at the external DB box.

The easy accessibility of the USB debugging port allows the other adjusted and appropriate code to be inserted into the microcontroller. The regulated noise at the appropriate sequence of the mathematics lesson proceeds to the microcontroller to perform the following tasks: (1) the microcontroller receives the electrical values that

initially represented the classroom noise level; and (2) the microcontroller compares the electrical values received to the coded information of the appropriate noise level at a particular phase of mathematical lesson. Therefore, in executing the coded information, the microcontroller would have to simultaneously track the time of the lesson and the appropriate noise level at that particular phase of the lesson and send an appropriate signal to the LED, that is, either green, yellow or red. When the microcontroller receives the data from the microphone via amplifier values of more than 5dbA above the required accepted noise level as inserted and programmed, the microcontroller would send a yellow signal into the yellow LED, which is produced as a yellow light or colour.

The green light of the SNR device is produced when the input data captured by the microphone via the amplifier has values that are within the range of the acceptable noise level. The values of the acceptable noise level get assessed by the microcontroller. The microcontroller sends a signal into the green LED, which is produced as green light or colour of the SNR device.

The yellow light of the SNR device is produced when the input data captured by the microphone via the amplifier has values that are between 0 to 10 dBA above the accepted noise level (0 <dBA <10). The microcontroller assesses the values. When the microcontroller senses that the input data captured from the microphone exceeds 5 dBA, it sends a signal into the yellow LED, which is produced as yellow light or colour of the SNR device.

The red light of the SNR device is produced when the input data captured by the microphone via the amplifier has values above 10 dBA of the accepted noise level (dBA >10). The microcontroller assesses the values. When the microcontroller senses that the input data captured by microphone exceeds 10 dBA, it sends a signal into the red LED, which is produced as a red light or colour on the SNR device. The SNR ability has a built-in programme to regulate the noise level in a mathematics lesson for a period of 40 minutes. The length of the period of a mathematics lesson is 40 minutes and this instructional duration was adapted based on the researcher's observations of several

mathematics lessons and their durations. For example, out of six schools that participated in the study, five used a 40 minutes period and the sixth school used a 50 minutes period. These time frames in schools influenced certain operations in the SNR device. For instance, at the elapse of 40 minutes, the SNR device remained stagnant in a green mode and paused for the teacher to operate it manually for the next lesson. Section 3.4 sets out the operation guidelines of the SNR device.

3.4 THE SNR DEVICE OPERATION GUIDELINES

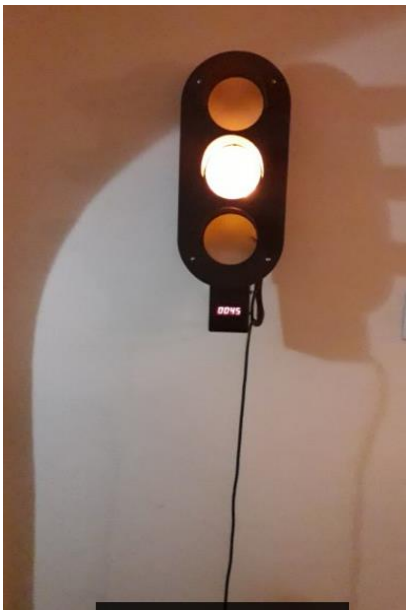
Section 3.4.1 discusses various ways that a teacher may use the SNR device:

3.4.1 The position of the SNR device in the classroom

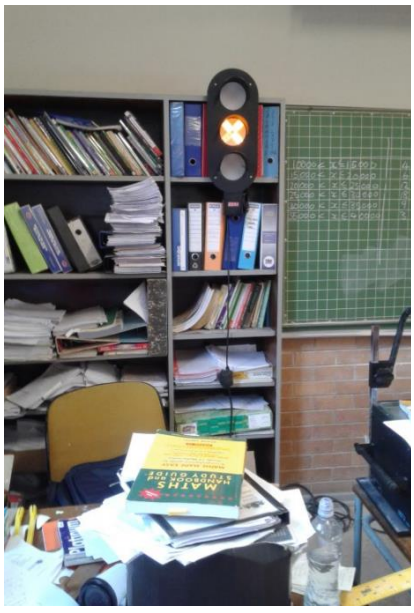
The SNR device may be placed in various positions in the mathematics classroom, depending on the size of the class, learners' seating arrangements and other classroom related factors. Figure 3.4 provides examples of some of the different ways to position the SNR device in the mathematics classroom.

Figure 3.4: Examples of methods of positioning of the SNR device in the mathematics classroom

The SNR mounted to its original stand



SNR mounted on the wall



SNR hooked on the cupboard

The SNR on its original stand: The SNR device can be mounted to its stand in front of the classroom. This option provides the flexible positioning of the SNR device at any spot in the classroom where the learners can be able to see it. This option may suit teachers who regularly change learners' seating arrangement in the classroom. The SNR device may be moved around to stand on the teacher's table or at any other elevated position.

The SNR mounted on the wall: The SNR device may be mounted on the wall. This option may be used in crowded classrooms with limited moving space. Also, this option of mounting the SNR device on the wall may be used in large classrooms so that the SNR device can be visible to all learners at an elevated position of the classroom wall.

The SNR hooked on any freestanding object: The SNR device has a hook that may be used to hang it on top of the cupboard or any freestanding object. This option may be used if a teacher keeps changing classrooms while learners remain in the classroom. For the purpose of the current study, in two out of six participating classes, learners had to remain in the classroom while the teachers would find the learners. The teacher would deliver the lesson and would vacate the classroom at the end and go to the next classroom. In this case, the option of moving the SNR device and temporarily hooking it onto the cupboard or onto any other elevated object would be ideal.

3.4.2 Switching the SNR device on and off

The SNR is an electrically operated device with 12 DC voltages. Therefore, the first step to operate the SNR device is to plug it on the power plug outlet. The second step is to use the switch to put the device ON or OFF. The empirical data used to determine the adequate noise level of each mathematics session and their timing are set out in Section 5.2.

3.5 SUMMARIZING AND CONCLUDING THE CHAPTER

This chapter has provided a detailed discussion on how the SNR is technically assembled. The chapter also described the main features that enabled the SNR device to control the noise levels in a mathematics classroom, namely, the use of colours green, red and yellow. The chapter demonstrated that the SNR device has a built-in feature to control learners' noise at the different stages of Grade 10 mathematics lesson. The next chapter presents the research methodology that was used to collect and analyse data in three schools' pilot studies and three schools' main studies.

CHAPTER FOUR
RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter presents the research methodology of the study and the methods used for data collection and analysis. The chapter describes the following processes: the research design; the population and sampling techniques; instrumentation; issues of reliability and validity; techniques used for data collection and analysis; and a discussion of ethical considerations.

4.2 THE RESEARCH DESIGN

The study followed the *intervention research design*, also known as the research-based design (see, Section 2.8). The rationale of selecting the intervention research design as the most suitable research design was based on the following: De Vos, *et al*. (2018), and Anderson and Shattuck (2012) recommended the use of intervention design when contemplating to develop a new technology or invention with the aim of improving the practice. Researchers in mathematics education are also positioning their studies towards the intervention research design (see, Getenet, 2015; Goff, 2016). Goff (2016) used the intervention research design to design an education programme that involves the adults in supporting the mathematical learning of children making the transition to school. In addition, Getenet (2015) used the intervention research design to design a professional development programme for mathematics teachers. It would seem that this research design is gaining ground in mathematics education research. The main motivating factors for the studies that use the intervention research are as follows:

- to develop or design an educational program; and in the context of this study the research design was used to inform the design of a technological device that was used to regulate and mitigate certain variables in the course of a Grade 10 mathematics lesson; and,

- to conduct an empirical study that permits the playing out of different phases meant to test and re-test the newly developed educational programmes or educational technological devices.

McBride (2016) and Herrington, et al (2007) point out that intervention research with its several research phases enables the researcher and the collaborators to progressively work together on the invention, test and redesign it repeatedly until it yields the results that improve the practice. This study followed the intervention research design consisting of five phases. The rationale for using five phases instead of six was motivated by the realisation that many activities that formed part of the preliminary stages of the current study had already been investigated at the masters' level. In addition, four phases would not have been ideal for the study because the study would implement several testing measures, also consisting of pilot study phases (see, Section 2.8). Phase 1 focused on the problem analysis, planning and information gathering. At this phase, the following research activities were performed.

- Identifying the inappropriate learners' behaviour as the possible main cause of learners' classroom noise;
- Proposing the SNR device as a mitigating effect or solution to learners' noise in mathematics lesson;
- Conducting literature review relating to learners' classroom noise level, its effects on learners' and teachers' classroom activities and establishing the sequencing of mathematics lessons in Grade 10 classrooms; and
- Studying the functionalities of the standard features of the Yacker Tracker

Phase 2 was also characterised by activities of the preliminary stage that focused on data collection in School A, designing and assembling the SNR device. In phase 2, the following activities were performed:

- The collection of data related to the noise level of each lesson activity of a mathematics lesson;

- The collection of data related to the sequencing of lesson activities in a mathematics lesson;
- The technical assembling of the SNR device, adjusting the noise level to be appropriate to each mathematics lesson activities; and
- Conducting a pilot study in School A using the assembled SNR prototype.

The phase 3 of the study, also known as a pilot study, was largely dedicated to collecting and analysing data in Schools A, B and C. In this phase the following activities were performed:

- Regulating and adjusting the noise levels of the SNR prototype;
- Playing out several components of the ABAB single research design in three different schools with SNR device;
- Conducting several lesson observations in three different schools in which the SNR device had been installed; and
- Analysing the data collected in the pilot study and looking for ways to improve data collection in the main study.

Phase 4 constituted the main study and was meant to focus on collecting and analysing data in Schools D, E and F. The main study activities closely replicated those of the pilot study and entailed the following:

- Conducting several research activities linked to the ABAB single research design in Schools D, E and F with SNR device;
- Conducting several lesson observations in three new schools in which the SNR device had been installed;
- Analysing the data collected from the pilot study and further adjusting the noise levels; and
- Analysing the final data of the main study in comparison with that of the pilot study.

Phase 5 was dedicated to the dissemination of the findings of the study. The following two activities were performed:

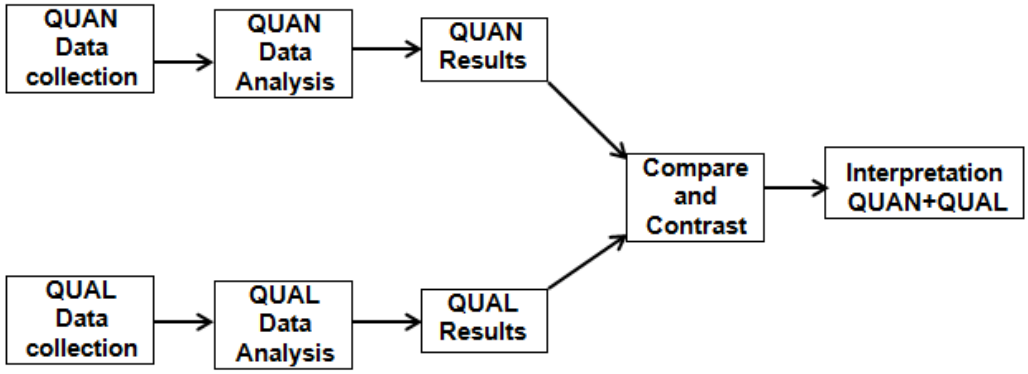
- Reporting the final findings of the study; and
- Outlining the study recommendations in terms of the use of the SNR device in different mathematics teaching area.

Concerns that are associated with learners' classroom noise that impede on their ability to learn and understand mathematics have been highlighted by previous studies (Hagoramagara, 2015; Langley, 2008; Ofsted, 2014; Woolner & Hall, 2010; Zhang, 2015). In view of this background, the SNR device was conceived to have the potential to mitigate the adverse effect of classroom noise on learning. The tool was developed and assembled, and thereafter introduced to the research field. From the conception of the SNR device, it underwent several tests and many adjustments on the engineering side. As for the SNR device's ability to control learners' noise in the classrooms, the device was used in the pilot and main study in the collaboration with six mathematics teachers and six Grade 10 classes. There has been constant data collection and analysis related to noise level, and many adjustments were made over a period of three years. Section 4.3 presents a discussion of the research methods used.

4.3 THE MIXED METHODS RESEARCH

Several studies that were conducted on intervention research have recommended the use of a mixed methods research approach (Anderson & Shattuck, 2012; De Vos, Strydom, Fouché & Delport, 2018; Goff & Getenet, 2017; McBride, 2016; Revees, 2006). Anderson and Shattuck, (2012) concur with Maxcy (2003) that it is logical to use the mixed methods in the intervention research because it progresses agnostically through using varieties of research tools and techniques to find a reality that is both plural and unknown (Maxcy, 2003, p. 59). Therefore, this study used a combination of the quantitative and qualitative approaches with the triangulation convergent model. Figure 4.1 depicts the triangulation convergent model adopted from Creswell and Plano Clark (2011).

Figure 4.1: The triangulation design (convergence model) adapted from Creswell and Plano Clark (2011)



According to Creswell and Plano Clark (2011), mixed methods research uses triangulation to converge and corroborate the results from different methods and designs by studying the same topic. Both quantitative and qualitative data are collected and analysed separately but simultaneously with equal emphasis. Thereafter, the separate results are merged together, compared and interpreted to provide a comprehensive understanding of a phenomenon (Creswell & Plano Clark, 2011, p. 78). In the current study, the data related to the levels of the classroom noise and the number of learners' errors during mathematics achievement tests were collected and analysed within quantitative perspectives. Data related to learners' inappropriate classroom behaviour were recorded and analysed quantitatively. Conversely, data related to the teachers' perceptions regarding the influence of the SNR device on classroom noise and learners' mathematical performance was collected and analysed using qualitative methods. The quantitative and qualitative results were merged, compared and interpreted to answer the research questions.

4.3.1 Population and sampling procedures

The population of this study consisted of (N=30) Grade 10 mathematics classes drawn from three educational school districts, namely, Johannesburg Central, Johannesburg East and Johannesburg West. The three districts are in the City of Johannesburg

metropolitan area in South Africa. In this context, the word *class* refers to a group of learners representing a learning family at a particular grade level, and at least one teacher would be assigned to teach this group a particular subject. The study used two-stage cluster sampling. In the first stage of cluster sampling, critical-case purposeful sampling was used to assign schools in clusters with similar characteristics. On the contrary, in the second stage of cluster sampling, simple random sampling was used to assign classes in pilot study and the main study.

4.3.1.1 Two stages cluster sampling

According to Johnson and Christensen (2012, p. 229), a two-stage cluster sampling consists of two stages rather than one. During stage one, a set of clusters representing a group of targeted individuals is randomly selected from all clusters within a population. During stage two, a random sample of individuals or participants is drawn from each of the cluster selected in stage one (Johnson & Christensen, 2012, p. 229). In the current study, during stage one, cluster sampling of 30 schools that participated were selected from the Gauteng Department of Education (GDE) database of ordinary secondary schools.

Thirty (30) selected schools were further clustered according to three categories using the following criteria, namely, ten schools were closest to the railway line; ten schools were located in the inner city; (and, ten schools had the oldest school building structures. In this regard, critical-case purposeful sampling was used to assign ten schools in each of these clusters (see, Section 4.3.1.2). In the second stage of cluster sampling, two schools in each cluster of ten schools were selected using a simple random sampling method (see, Section 4.3.1.3). In each criterion, one Grade 10 mathematics class was randomly assigned to participate in the pilot study and the other school to participate in the main study. Eventually, six schools with their six Grade 10 mathematics classes and their six respective teachers from a targeted population of 30 schools participated in the study.

4.3.1.2 Critical-case purposeful sampling

The researcher used the critical-case purposeful sampling to select participating schools. Johnson and Christensen (2012, p. 237) state that a researcher who uses the "critical-case purposeful sampling" selects participants that are believed to be particularly important cases and use them for in-depth enquiry of the study. The researcher who uses the critical-case purposeful sampling is effectively saying: "If it happens with this particular group of participants, it will happen to all participants in similar cases, and if it does not happen here, it will not happen everywhere" (Johnson & Christensen, 2012, p. 237). In determining the population of this study, the researcher relied on the available literature and information reflecting on schools that are affected by the high noise level. For instance, WHO (2018) and several studies on the noise levels in schools unanimously agree that schools situated in locations like airports, near the railways, inner cities schools and schools with old building structures are more likely to be affected by the high level of noise. These studies include Kristiansen *et al*., 2011) in Denmark; Shield *et al.,* (2010) in United Kingdom; Golmohammadi *et al*. (2010) in Iran; Mohan and Rajagopal (2010) in India; Zannin and Zwirtes (2009) in Brazil; Zannin *et al*. (2008) in Brazil, Sato and Bradley (2008) in the USA and Lundquist *et al*. (2003) in Sweden) in Chan *et al*. (2015).

Initially, the researcher had planned to use 40 schools that fit the following criteria:
(1) ten schools near the airports; (2) ten schools closest to the railway; (3) ten schools within the inner city (4); and, ten schools with the oldest school building structures.
However, it was not feasible to get ten schools fitting the first criterion. In the location where this study was conducted there was only one domestic airport, namely, Lanseria Airport, situated in the Johannesburg[2] metropolitan. At the time of conducting the current study, there were few schools next to the Lanseria Airport that could have constituted a criterion of population of ten secondary schools. Hence, the study used a population of 30 schools.

2. The Johannesburg international airport, also known as O.R. Tambo airport, is located in the area known as Ekurhuleni metropolitan, which is located in the East Rand region of Gauteng, South Africa. OR Tambo international airport is about 20 kilometres away from Johannesburg Central.

The 30 schools were purposefully selected from the Gauteng Department of Education (GDE) ordinary secondary database. These schools were selected from three educational school districts in the Johannesburg metropolitan. For equal representation of the population with same characteristics, each cluster was assigned with equal number of schools (see, Section 4.3.1.1).

4.3.1.3 Simple random sampling

At the beginning of the study, the researcher found out if all selected schools were offering mathematics in Grade 10. If a school had more than one Grade 10 mathematics class, the school management was given the prerogative to avail any class of their preference to participate in the study. Simple random sampling method was used to select two Grade 10 mathematics classes from each cluster that participated in the study. In each cluster, the researcher wrote the names of all ten schools and placed them in three different bowls according to their cluster and closes each bowl with a lid. The researcher randomly chose the first bowl, and it happened to be for the schools located in the inner city. The researcher shuffled the names in the bowl by shaking the bowl for five seconds and then the first name was drawn. The first name of the school to be drawn was assigned to the pilot study and was named “School A”. The remaining nine names in the bowl were shaken again. The second name that was drawn was assigned to the main study and referred to as “School D”.

The same procedure was repeated with the second bowl. The second bowl consisted of the schools that were characterised with the oldest school buildings. The first name to be drawn out of the bowl after shuffling was assigned to the pilot study and was named “School B”. The second name to be drawn from the bowl after the shuffling was assigned to the main study and was named “School E”. Similar procedures of random sampling of schools were repeated with the third bowl. The third bowl consisted of the schools located near the railway line. The first name to be drawn out of the bowl after shuffling was assigned to the pilot study and named “School C”. The second name to be drawn from the third bowl after the shuffling was assigned to the main study and was named “School F”.

In compliance to the research ethical guidelines the identities of participating schools were made to remain anonymous. For this reason, the six Grade 10 mathematics classroom that participated in this study for a period of three years are represented in this report with the alphabet letters A, B, C, D, E and F. At the same time, the validity and the reliability of research findings depend on a well-defined population and participants. Table 4.1 summarises the characteristics of the schools used in the study. The main school characteristics and the profiles of Grade 10 learners who participated in the study are discussed in Sections 4.3.1.3.1, 4.3.1.3.2 and 4.3.1.3.3.

Table 4.1: Characteristics of schools that participated in the study

School code	Location of the school	Number of learners	Study phase in which research activities took place
A	Located in the city/ the suburb	32	• Preliminary study • Pilot study
B	Located in the old buildings (over 100 years old)	29	• Pilot study
C	Close to the railway line (about 50 metres away from the railway line)	38	• Pilot study
D	Located in the city/ the suburb	28	• Main study
E	Located in the old buildings (over 100 years old)	35	• Main study
F	Close to the railway line (about 10 metres away from the railway line)	43	• Main study

4.3.1.3.1 The schools located in the suburban environment

Schools A and D were sampled from a suburb-like setting in Johannesburg (Table 4.1). As noted by Machord and Mckay (2015), majority of the schools located in the surburb of Johannesburg were previously considered as model C. During the apartheid regime, model C schools were considered to be for the wealthy, elite, white community. Machord and Mckay (2015) observed that learners' population in the ex-model C schools are no longer classified along the racial line, as the elite are becoming increasingly multiracial. In terms of economical status, South Africa is becoming a two-tiered public education system. On one hand, there are well-resourced, academically successful multiracial ex-Model C schools, located in mostly wealthy suburbs, and on the other hand, under-

resourced, academically less-successful schools, predominantly located in the townships and rural areas with an almost entirely all black learner population (De Kadt, Norris, Fleisch, Richter & Alvanides, 2014). Therefore, the majority of learners from the surburban schools who participated in the study were from middle to higher income households. School A participated in the preliminary stage of data collection, that is, during the pilot study, while school D participated during the main study. The sampled Grade 10 mathematics class A consisted of 32 learners, and there were 28 learners in School D. The rationale of using of schools located in the suburbs of Johannesburg was motivated by researchers who had claimed that traffic noise may have some influence on learners inside the classroom (Christidoo, Dimitriou, Papadopoulou & Grammenos, 2015). In Johannesburg the surbubs, Mahapa, (2016, p. 38) mentioned that the sources of noise that affects the residents in Johannesburg surbubs are from the barking dogs, revving and honking cars, noise from restaurants, bars, clubs, and sports fields. Mahapa (2016) suggests that the same noise problems may be experienced in the others major metropolitan cities in South Africa, namely, eThekwini, Tshwane and Cape Town. Mahapa (2016) and De Kadt et al. (2014) may suggest that the characteristics of the learners who participated in this study resemble the population of other metropolitans' cities in South Africa in term of population dynamics and factors that influence noise level inside the classrooms.

4.3.1.3.2 The schools located near the railway line

Schools C and F were sampled from areas located near the railway line in the Johannesburg metropolitan. School C participated in the pilot study while School E participated in the validation stage of the data collection. In validation processes, data in School C were compared to data in School F to account for the consistency and stability of the two sets of data in the same noise environment. Machord and Mckay (2015, p.155) indicated that train transportation in the City of Johannesburg is the less expensive compared to traveling using minibus taxis because it is subsidised by the city. Hence, learners in schools that were located near the train stations would usually be those who come from Soweto and other former 'black' townships such as Alexandra, Tembisa and

Kathlehong. Machord and Mckay (2015, p.156) also indicated that majority of learners live in upper working class to lower middle class. Ordinarily, parents would send their children to these schools with an expectation of a good education from the City of Johannesburg while using the lowest mode of transport (Machord & Mckay, 2015, p.156). One of the participating schools was a non-fee-paying school, implying that the government or the state would fund all the schooling expenses in such a school. This may suggest that learners in non-fee-paying school come from homes with low income and low socio-economic backgrounds. As a result of the low cost of transportation to go to school, and low school fees or in some cases non-fee-paying schools, the schools located near the railway line have a reputation of being overcrowded, which means that the learner-teacher ratio could be more than 32:1.

In School C, the sampled Grade 10 mathematics class had 38 learners and there were 43 learners in School F who were sampled. The rationale of using schools located near the railway lines by a number of researchers who claimed that the noise of the honking and moving trains might have some influence on learners inside the classroom (Grubliauskas, Strukcinskiene, Raistenskis, et al., 2014; Nielsen, 2009). For instance, School C had the surrounding fence that was adjacent to the railway line, therefore continuously exposing school's classrooms to the invading noises of the passing trains. The classroom was about ten metres from the railway line. The school structure was set up as a mobile classroom, also known locally as *zozo*. Furthermore, learners located near the railway line were also known to have classroom discipline problems similar to those in South African township schools. Hence, the researcher saw it as an ideal environment to test how the SNR device influences the participants' classroom discipline problems.

4.3.1.3.3 The schools located in the old building

Schools B and E were sampled from Johannesburg regions in which schools' building structures were relatively old. These would be schools in the parts of Johannesburg that consisted of old and dilapidated building structures. Schools B and E were more than 100 years old. School B was used in the pilot study while School E participated in the validation stage of data collection. In School B the sampled Grade 10 mathematics class consisted

of 29 learners and in School E there were 35 learners. Researchers who claimed that older buildings were not designed with the appropriate absorption coefficient, therefore creating sound reverberations (Aguilar & Tilano, 2019; Lesna & Skrodzka, 2010), motivated the rationale of using some of the oldest schools' buildings in Johannesburg. For instance, Aguilar and Tilano (2019, p.54) point out that in older schools, classroom noise levels and poor speech intelligibility are caused by poor maintenance of the classroom, such as broken windows panes and the lack of sound absorption materials. However, these claims did not seem to be the case in sampled schools with older building structures. The researcher observed that in older school buildings, the thickness of the classrooms' walls was thicker than the new classrooms, which make it possible to block off the noise from outside the classroom. In addition, the classrooms are fitted with large windows, without broken glasses. In South Africa, National Heritage Act of 1999 protects buildings older than 60 years. This could be one of possible explanation of the good maintenance of the classrooms located in the older school could in South Africa. In this current study, the advantage of using the sampled schools from old building structures is that it allowed the study to be conducted on learners from the middle economic class. One of these schools also happened to be an exclusively boys' school. This provided the added opportunity to test the claim that boys are noisier than girls.

4.3.1.3.4 Teachers' input on the functionality of SNR and their role in the study

The cooperation between the class teachers, the researcher and the learners played an important role for this study to conducted and completed successfully. Six teachers who were teaching mathematics in six Grade 10 classes that participated in the study voluntarily consented to participate in the study. These teachers consented to be present while the research took place in their respective classrooms. They agreed to continue with their normal teaching activities while the research took place in their classrooms. In this arrangement, the researcher was able to observe and document aspects of what would constitute learners' inappropriate classroom behaviour and measuring and recording the classroom noise levels that would emanate during teachers' lessons. The researcher visited these schools once a week to conduct lesson observations and /or to record the noise levels during the lessons. All teachers helped the researcher to collect assent forms

from learners (Appendix H). Teachers also participated in completing the questionnaires that were administered at the early stages of the data collection phase (Appendix D).

The analysis of data from teachers' questionnaires assisted in revealing teachers' views on the noise level in their mathematics lessons (see, Section 4.4.1). During the pilot study, the researcher constantly interacted with teachers to get their inputs on how to administer the SNR device in a way that would improve effectiveness of their classroom teaching environments (see, Section 4.3.4.2). Among teachers' suggestions they advised, (1) that the SNR device should have a mounting stand to position it anywhere in the classroom, (2) that the SNR device should have the bracket to be mounted on the wall and a part to hook it on the cupboard or any other freestanding instrument (see, Section 3.4.1). Teachers assisted in the construct validity of the learners' post-test questionnaires (see, Section 4.6.1.2). One month ahead of the finalisation of each component of research activities, the researcher administered the mathematics achievement tests to the learners (Appendix A, B and C; see, also, Section 4.4.5). During the last month of the pilot study, the class teacher allowed the researcher to administer the achievement tests to learners. The tests were administered in a space of 10-15 minutes at the end of the lesson per week. This arrangement allowed the researcher to administer at least one part of the mathematics achievement tests to the learners (see, Section 4.5.2.6).

The researcher and participating teachers agreed to this arrangement of 10-15 minutes at the end of the lesson in an effort to comply with a part of the condition for research approval by GDE, which requires researchers to minimise their interference with the teaching and learning time (see, Appendix K). The four weeks arrangement of administering the achievement tests in parts or segments, as explained in the preceding lines, tended to manifest limitations for the study. For instance, at one point, School A did not participate in the achievement test that addressed the basic and mental calculations. This shortfall was orchestrated by an industrial action that teachers had embarked on at the time of conducting the study. The industrial action, commonly known in South Africa as a strike action, prohibited teachers from attending to their classroom lessons. This strike action coincided with the time that was planned to administer the achievement tests

based on mental calculations and teachers at the affected schools had abandoned teaching duties. While these unforeseen events were unfolding, the GDE permission to conduct research in selected schools was about to expire the following week. During the last month of the research in the main study, the arrangement of the class teacher sparing between 10 -15 minutes of the lesson per week was changed. In these schools, the researcher and teachers agreed that using one uninterrupted session to administer the mathematics achievement test would cause less inconveniences for both teachers and the researcher while still complying with GDE research requirements. The researcher only requested between 40 and 80 minutes, which is a period of double lesson for mathematics in Grade 10, to administer all the mathematics achievement tests to the learners including the learners' post-test questionnaires.

The advantages of using just one period of 40 to 80 minutes instead of 10 to15 minutes in four weeks to administer all the mathematics achievement tests to the learners were that the arrangement would be inconvenient to the teacher and the researcher. The use of one period of 40 to 80 minutes also made it possible to mitigate the potential threats to the internal validity, which could possibly manifest themselves owing to the length of time between the administering of the pre-test and the post-test. These validity threats could manifest themselves in the form of history, maturation, testing, and attrition (see, Section 4.6.3.1). The good relations between the class teachers and the researcher facilitated the implementation of needed adjustments in terms of the research methods within the parameters of the intervention research design (see, Section 4.2).

4.3.1.3.5 The role of Grade 10 mathematics learners in this study

This study consisted of 205 learner participants who were taking mathematics in Grade 10. These learners were purposefully and randomly sampled from 30 schools. The 205 learners were drawn from six mathematics classes in six schools (see, Table 4.1). After consenting their participation in the study, learners fulfilled two roles.

4.3.1.3.5.1 The first learners' role in the course of conducting research

Learners were expected to be in their respective classrooms during mathematics lessons and they were expected to continue their routine learning activities when the researcher was observing and recording learners' inappropriate classroom behaviour, measuring and recording the classroom noise level. During lesson observations and the recording of the noise level, the researcher would remain a neutral non-participant observer, and would not interfere with any flow of the lesson or make any input on the lesson.

4.3.1.3.5.2 The second learners' role in the course of conducting research

A month ahead of the finalisation of research activities in each of the research phases learners were expected to participate in writing three sets of Grade 10 mathematics achievement tests, namely, the algebra test; the basic mental and calculation test; and the geometry test. Learners were encouraged to exert themselves fully while writing these tests.

4.3.2 The multiple-baseline research method consisting of A-B-A-B research design

McMillan and Schumcher (2012, p. 306) define the A-B research design as the baseline and intervention design in a single subject of quasi-experimental design. The procedure in the A-B research design is to observe the target behaviour until it occurs at a consistent, stable rate, a baseline or (A) condition. An intervention is then introduced to the environment in which the baseline data has been collected and the intervention condition is labelled (B). The A-B-A-B research design refers to a repetitive A-B research design. Gay, Mills and Airasain (2011, p. 298) note that the A-B-A-B design has a better internal validity than the A-B design owing to its nature of repetitive research activities that allow the researcher to identify and correct associated shortfalls.

The current study used the A-B-A-B single-subject experimental research design to determine the causal inference of the SNR devices in influencing, if possible, learners' classroom activities relating to noise, disruptive behaviour, off-task behaviour and the influence on ALT (Academic Learning Time). Creswell (2012, p. 316) asserts that a single-

subject quasi-experimental research design implies that the intact groups are used instead of randomly assignment participants. McMillan and Schumcher (2012, p. 305) further posit that in a single subject design, the effects of an independent variable are explored on each subject of the study, not collectively. In employing the A-B-A-B design, the current study collected and analysed data to explore the influence, if any, of SNR device on each of the four independent variables, namely, learners' classroom noise, disruptive behaviour, learners' engagement, teaching and learning time, and the ECL individually.

4.3.3 Single A-B research design

McMillan and Schumcher (2012, p. 306) define the A-B design as baseline and intervention design in a single subject of quasi-experimental design. The procedure in the A-B design is to observe the target behaviour until it occurs at a consistent, stable rate, a baseline, or (A) condition. An intervention is then introduced to the environment in which the baseline data have been collected and the intervention condition is labelled (B). The A-B design was employed whenever mathematics achievement tests were administered to the learners. The first achievement test to be administered to the learners was an algebra test aimed to test learners' achievements in following mathematical procedures, rules, evaluation, and problem skills. Questions in the algebra test were administered to the learners by the researcher using the printed question papers. Learners were expected to answer in the answer book that was provided by the researcher. The test was first written in the classroom with the noise level ranging from to 50 – 60 dBA, which was considered to be an appropriate noise range when writing mathematics tests. To achieve this constant noise level, the SNR device was installed in the classroom.

A Grade 10 algebra test with similar content was thereafter written in the classroom with the noise level ranging from to 70 – 80 dBA. To achieve this constant noise level, local popular songs were played in the classroom and amplified to 70 – 80 dBA. The rational of playing the music instead of generating other forms of noise in the classroom was in compliance with the research ethics (Section 4.9). In addition, the type of music that was played tended to contribute in eliminating the extraneous variables that could have

affected the internal validity of the study such as tiredness and stress (see, Section 4.6.3.3). The results from the data collected in the classroom with the noise level ranging from 50 to 60 dBA were compared with the results from the data collected in the classroom with the noise level ranging from 70 to 80 dBA. In this manner the administration of the algebra test followed the A-B experimental design.

The second achievement test that was administered to the learners consisted of the basic mental and calculation activities. The basic mental and calculation test aimed to assess learners' listening skills in retrieving and using basic mathematics knowledge. The test was administered to the learners in the classroom with the noise level ranging from 50 to 60 dBA. Thereafter, the results were compared to the similar data collected in the classroom with the noise level ranging from to 70 – 80 dBA. The researcher read out items from the mathematics questions relating to the basic mental and calculation, and learners were required to write their answers in the answer book provided. To achieve the constant noise level of 70 to 80 dBA local popular music was also played in the classroom. To maintain the constant noise level of 50 – 60 dBA the SNR device was installed in the classroom. In this manner, the administration of the basic mental and calculation test also followed the A-B experimental design.

Lastly, the third achievement test was the geometry test that aimed to assess learners' ability in using their sense of vision and determining the size of angles in different triangles and in parallel with transversal. This test also assessed learners' ability to recall some of Euclidean reasoning skills that they had used to determine the sizes of angles. The researcher projected the test questions on the screen for learners to see and the latter responded using the provided answer books. The test session took with the noise level controlled by the SNR device from 50 to 60 dBA. Thereafter, another geometry test with similar content to the first test was administered to the learners in the classroom noise level ranging from to 70 – 80 dBA. To achieve the constant noise level of 70 to 80 dBA, a local popular music was also played in the classroom. The researcher followed the A-B experimental design when administering this test. Table 4.2*:* outlines the sequence that

was used to administer mathematics achievement tests to learners within the A-B-A-B research design during the pilot study and the main study.

Table 4.2: Mathematics test in the pilot study and the main study within the ABAB design

School and type of assessment administered	Algebra		Post-test questionnaire	Basic and mental calculations		Post-test questionnaire	Geometry		Post-test questionnaire
School A	A	B	No			No	A	B	No
School B	A	B	No	A	B	No	A	B	No
School C	A	B	No	A	B	No	A	B	No
School D	A	B	Yes	A	B	Yes	A	B	Yes
School E	A	B	Yes	A	B	Yes	A	B	Yes
School F	A	B	Yes	A	B	Yes	A	B	Yes

In Table 4.2, input “A” represents the classroom environment without the SNR device and input “B” represents the classroom environment without the SNR device. In addition, the “Yes” input indicates that learners took a particular assessment activity while a “No” input indicates that the assessment activity was not taken. Table 4.2*:* shows that during the pilot study in schools A, B and C learners did not complete the post-test questionnaire. The researcher had imagined that by analysing mathematics errors that the learners made during the achievement test would provide sufficient information to understand the effectiveness of the SNR device in increasing learners’ accurate answers. However, the researcher noted that some interpretation may be prone to speculation. The absence of the learners’ feedback from the post-test questionnaire denied the researcher an opportunity to interpret learners’ mistakes and errors that had been identified in the achievement tests. The researcher was concerned that other confounding variables could be influencing learners’ performance in the mathematics achievement tests. In the main study, learners’ post-test questionnaire was incorporated in the study designs to strengthen the interpretation of data generated through mathematics achievement tests.

In the main study, the researcher was then able to compare learners’ responses in the post-test questionnaire and learners’ errors in the achievement tests and was able to

establish if learners' achievement in the tests were the results of the variation of the noise level in the classroom. Table 4.2*:* shows another limitation in the pilot study. School A did not participate in the basic and mental calculations achievement tests. At the time of administering the mental calculations achievement test in School A, there was a teachers' strike action that halted all teaching and learning activities in all schools. Unfortunately, the GDE's permission to do research in schools would be expiring in the week that followed. This meant that the test could not be given to the same learners the following year as there would be another group of learners. This limitation was addressed in the main study. In the main study, the researcher requested class teachers to arrange a relatively longer assessment time or session to enable learners to complete all mathematics achievement tests.

4.3.4 Research phases

The research activities in the study were divided in three phases that played out as follows:

4.3.4.1 Preliminary phase: The manufacturing phase

The preliminary phase, also referred to as the manufacturing phase, constituted the first phase of the research activities of the study. In this phase, preliminary data related to the noise level in the Grade 10 mathematics classrooms and the duration of each activity of the lesson were collected in School A (see, Section 5.2). Furthermore, data related to noise level in mathematics classroom was collected using the sound level meter and were recorded as baseline or the starting reference of the research. Data collected in this phase were used at the early stages of assembling of the SNR prototype (Section 3.2).

4.3.4.2 The pilot study

The second phase of the research constituted the pilot study component. Data related to the noise level were first collected at the baseline where Grade 10 learners wrote three mathematics achievement tests in a classroom with a noise environment ranging from 70 – 80 dBA. Thereafter at the intervention phase, Grade 10 learners wrote mathematics achievement tests in a classroom in which the SNR device had been installed, and the sound meter monitored that the noise was ranging from 50 – 60 dBA (see, Section 5.3).

At the intervention stage, the SNR device was installed in front of the classroom to generate a warning signal of the noise level.

In the pilot study, data related to learners' inappropriate classroom behaviour in the classroom were collected using the lesson observation instruction guideline, in adherence to use A-B-A-B single-subject experimental design in Schools A, B and C (Sections 1.10.4 & 1.10.5). The experiments to determine the extent to which the noise level exerted the ECL was performed using three types of mathematics achievement tests: Algebra achievement tests, basic and mental mathematics calculations achievement tests, and the Euclidean geometry achievement tests. Mathematics achievement tests were administered to learners in three Grade 10 classes in in line with the A-B single design (see, Section 4.3.3). The purpose of the pilot component was to further understand the phenomenon of noise level, and to establish the reliability of the instruments of data collection (see, Section 4.6.1). Following the pilot study, some adjustments were made on the SNR sequence and noise level and the research instruments.

4.3.4.3 The main study

The third phase of the study constituted the playing out of research activities in the main study. The main study followed the same research procedures that were used in the pilot study. Data were collected in three different schools referred to as Schools D, E and F). To collect data, the study used the instruments that had been refined in the pilot study (see, Section 4.5.3).

4.4 DATA COLLECTION INSTRUMENTS

This section discusses the development of data collection instruments and how they were used in the field of research. According to Suter (2012, p. 193), in educational research, data collection instruments could constitute tests, forms or other tools used in gathering data. In the current research, each of the five main variables of the study were associated with an appropriate data collection instrument (see, Figure 2.3).

4.4.1 Teacher questionnaires

Six questionnaires were administered to six mathematics teachers who participated in the study. Teachers' questionnaires were administered at the early stage of the data collection phases of the pilot study and the main study. Goff and Getenet (2017) highlight the advantages of administering the questionnaires to study respondents at the early stage of data collection. Furthermore, Goff and Getenet (2017) postulate that it is an important part of intervention research to involve the practitioners, who were teachers in the context of this study, who will use the invention to benefit the community, which is represented by learners in the current study.

The items in the questionnaires were designed by the researcher and were reviewed by the researcher's colleagues who teach mathematics in Grade 10 (see, Section 4.6.1.2). The teacher questionnaire was designed to elicit responses from Grade 10 mathematics teachers regarding their perceptions and attitudes toward the noise level and their experiences both inside and outside mathematics classrooms (see, Appendix D). The researcher opted to use the teachers' questionnaire instead of the interview because it was seemingly not necessary to go deeper in understanding the mathematics teachers' perspectives of the classroom noise level during their teaching. It became clear that teachers' questionnaire data and learners' responses in the post-test questionnaire would suffice in answering the sub-research question 2 of the study.

Teachers' questionnaires consisted of close-ended items that would be answered by means of different Likert scale measurements (see, Table 4.11*:* & Table 5.3). The teacher questionnaire consisted of ten close-ended questions. Question 1, 2 and 3 focused on the extent to which teachers experienced learners' inappropriate behaviour caused by classroom noise. Question 4 and 5 focused on the effects of the noise level on the delivery of mathematics lessons. Question 6, 7, 8 and 9 focused on teachers' perceptions of the source of the noise level inside, outside the classroom and outside the school premises. Question 10 was designed to provide the understanding of the extent to which learners would complain about the noise level in the classroom. In general, the items in the questionnaires had been constructed to elicit responses from Grade 10 mathematics

teachers about their perceptions and attitudes toward the noise level and their experiences both inside and outside mathematics classrooms in the South African context (see, Section 4.6.2.2).

4.4.2 Yacker Tracker

The features of a classroom tool called Yacker Tracker closely resemble those of the SNR device. Yacker Tracker is a Walmart product in the USA. The Yacker Tracker is a traffic light that monitors the decibel level in the classroom. The unit signals a green light when the sound levels is within the acceptable range, showing yellow when the sound level exceeds the acceptable limit, and red when the sound level reaches 15 decibels above the adjustable sound level meter. In this study, the Yacker Tracker was used in the following three procedures:

- to collect data in school A at the preliminary phase, which was also referred to as the manufacturing phase;
- to synchronize the noise level measurement of the SNR device with the sound level meter; and
- to establish the concurrent validity of the SNR device.

At first, the Yacker Tracker was for data collection in School A ahead of the inception and the assembling of the SNR device. During the data collection in School A, the Yacker Tracker was positioned in front of the Grade 10 classroom with its traffic light facing the learners. The researcher informed learners that if the noise exceeded the recommended noise limit, the Yacker Tracker light would generate a red light. In the classroom with the Yacker Tracker, the researcher would monitor and record the classroom noise level and observe if learners would comply with the red signal of the Yacker Tracker by reducing their noise level. In addition, the researcher would observe and record learners' inappropriate behaviour in the classroom and see if the reduction of noise level would subsequently reduce the incidences of inappropriate learners' behaviour. At this early stage of the study, the Yacker Tracker was used to determine if the features of the SNR device would influence learners' classroom noise and behaviour.

The advantages of the SNR device over the Yacker Tracker is that the SNR device could be programmed to change the settings of its noise level as the phases of the mathematics lesson were changing. The introduction of the Yacker Tracker in the classroom, or in the Grade 10 mathematics lesson, at the very beginning of data collection helped to determine the effectiveness of the SNR device and its efficient workability. De Vos, *et al*. (2018) emphasise that the testing of a working model in field conditions could determine positive outcomes in intervention research.

The data generated by the Yacker Tracker in School A were influential in influencing the assembling and enhancing the engineering aspects of the model of the SNR device. This part and associated activities entailed several laboratory testing procedures and alterations up until the SNR device was considered to be optimally working. Lastly, the Yacker Tracker device was used to establish the concurrent validity of the SNR device (see, Section 4.6.2.3). In terms of the concurrent validity, the Yacker Tracker was used to account for the accuracy of the colours of the SNR device in sending the correct warning signal during mathematics lessons. The colour signals emitted by the new device, the SNR device, of the specific level of classroom noise were synchronised with the colour signals of classroom noise level of an existing well-functioning device, that is, the Yacker Tracker.

4.4.3 Sound level meter

During a preliminary phase the sound level meter (SLM) was mainly used for data collection. This tool was also used for this purpose in the pilot study and in the main study (see, Sections 0 to 4.5.3). The SLM was used frequently to measure learners' noise level when the researcher visited the classroom to collect more data for the study (see, Section 4.5.2.2). According to Kutz (2013, p. 451), a typical SLM consists of a condensed microphone preamplifier, the data acquisition hardware and the noise level software, a display to present the results and the storage system to save the recorded data. In the current study, the class 2 of SLM was used. Kutz (2013, p. 452) recommended the use of the class 2 of SLM when measuring the sound pressure of high frequency range. The

SLM was observed to be compliant with the international standard IEC 61672-1 (Kutz, 2013, p. 452). The data gathered through the SLM was represented in continuous sound level ($L_{eq\ 2sec}$). Kutz (2013, p. 452) argues that (L_{eq}) measurements are advantageous because they provide an average noise exposure over a given period of time. In this study, the sound level meter captured the noise level every two seconds. This helped the researcher to account for all types of noise interference in the classroom.

In using the sound level meter to capture the noise level inside the classroom the researcher closely complied with the South African Act's noise control regulations in terms of section 25 of the Environmental Conservation Act 1989 (Act No. 73 of 1989). The Act recommends that the SLM be positioned at a height between (1,2 and 1,4) metres from the floor or ground and at least 1,2 metres away from the wall. These guidelines were closely followed. During the pilot phase of data collection related to the noise level data collection in the classroom, the researcher sat at about 1,5 meters away from the wall at the back of the classroom. He held the sound level meter with the left hand at the height of 1,2 meters, and manually record instant noise every two minutes, using the right hand. However, in the main study, the researcher made some improvements that resulted in the strengthening of the internal validity of the instrumentation process. Fidêncio, Moret and Jacob (2014) reviewed several studies conducted on the level of noise in schools in many countries and found some inconsistencies in the data capturing and recording processes. Furthermore, Fidêncio *et al*. (2014) recommend the use of noise level software and a computer program connected to the sound level meter to facilitate the standardisation of capturing and recording data related to noise level. In terms of recording noise level in the main study, the researcher used noise level computer software instead of recording the data manually, which was in line with Fidêncio, *et al*.'s (2014) recommendations (see, Section 4.6.3.2).

The use of the sound level meter with the noise level computer software strengthens the instrumentation's internal validity because the instant noise level in dBA is captured every two seconds and instantly changed into a graph. In the main study, the use of the noise level software and the recording of the instant noise every two seconds increased the data

internal validity and reduced recording errors that may have resulted from manual recording (see, Section 5.4.2).

4.4.4 Lesson observation instruction guidelines

For the duration of study, the researcher observed some of Grade 10 mathematics lessons in six different classrooms using the lesson observation instruction guideline (Appendix E). The researcher would visit the Grade 10 mathematics lesson one day in a week to observe the lesson. The lesson observation guideline consisted three sections, namely, (i) the section to record data related to classroom noise; (ii) the section to record data related to incidences of learners' inappropriate classroom behaviour; and, (iii) the section to record the pacing of a Grade 10 mathematics lesson (see Appendix E). During the preliminary and pilot phases of data collection, data related to the noise level in the classroom was captured on the lesson observation instruction guideline. However, in the main study, the lesson observation guideline was not used to record the classroom noise level because it was done using noise level computer software.

Section A of the lesson observation instruction guidelines was designed to capture teachers' pacing and the timing of the different parts of a Grade 10 mathematics lesson. The researcher observed and documented the lesson observation instruction guidelines and the duration of each of the following phase of mathematics lesson:

(i) the warm-up and review and previous homework; (ii) the introduction of the new concept; (iii) the work examples practice and exploration; (iv) the assessment or consolidation test; and, (v) the closure and administration. Having conducted several lesson observations during the preliminary and pilot phases of data collection, the average duration of each phase was determined. The main purpose of recording the timing of mathematics lessons over a period of time was to get a general pattern of the flow of the mathematics lesson (see, Section 3.2.2 & Table 3.1). The established pattern of the flow and pacing of different activities in the mathematics lesson formed an integral part of the new SNR device because the SNR device has a built-in programme capable of changing

its noise level settings as the phases of the mathematics lesson keep changing (see, Section 5.2).

Section B of the lesson observation instruction guidelines was designed to document learners' disruptive and off-task behaviour. In developing items that would assist the researcher to observe learners' inappropriate behaviour in the mathematics classroom the following three studies were reviewed:

(1) Algozzine (2012) provides a list of learners' inappropriate behaviour in the classroom; (2) Ofsted (2014) provides a list of inappropriate classroom behaviour; and, Hagoramagara (2015) provides a list of disruptive and off-task behaviour generated by learners in mathematics classrooms. In the instrument, eight items related to learners' disruptive behaviours and seven items related to learners' off-task behaviours that appear prominently in all the three studies were used in the learners' classroom behaviour sheet that was used for class observation (Appendix E).

In collecting data about learners' noise in the classroom, the researcher made a distinction between learners' noise related to the learning itself and learners' noise that would be intended to disrupt learning. Salum and Shahrill (2014) suggest that when one group of learners generates classroom noise that causes disruption, it encourages the off-task behaviour of the other group. The researcher used one sheet to document learners' disruptive behaviour and learners off-task behaviour and these data were used to answer the sub-research questions 3 (see, Table 6.3 & Section 6.3.2.3).

4.4.5 Music to influence mathematics classroom noise level

Several researchers are exploring ways to incorporate music classroom mathematics teaching (Viladot, *et al*., 2017; An, Tillman, Boren & Wang, 2014; Dobrucki, Kin & Kruk, 2013). Studies that explore ways to incorporate music in teaching mathematics argue that music may bring about the learning environment that motivate and stimulate learners' ability to remember mathematical procedures and some mathematical patterns. However,

there seem to be some challenges that make it difficult to incorporate the use of music in teaching mathematics classrooms.

Firstly, An, *et al.* (2014) explored the effects of integrating music-themed mathematics activities. They found that the most prevalent challenge in music-induced mathematics classroom environment was that music made it difficult for learners to listen and follow instructions given by the teacher. Secondly, An *et al*., 2014 noted that another challenge mentioned by the teachers was that music made it difficult for them to keep up with the instructional time, therefore, leaving them with insufficient for other activities such as assessing the learners. Viladot, *et al.* (2017) found that the challenge to incorporate music in mathematics lessons was because mathematics teachers may not necessary be interested or expert in music. On the other hand, music teachers may as well be lacking interest in mathematics. Furthermore, Viladot, et al. (2017) report that a key challenge was that the teachers complain that they do not have enough time to teach music at the same time completing the assigned mathematics contents.

Despite the challenges of implementing music in mathematics teaching, the researcher in this current study noted that the literature that explore ways to incorporate music in teaching mathematics do not consider music as causing an emotional, mental or physical harm to the learners or the teachers, particularly when the music noise level is closely monitored. Given the negative effects of noise pollution in education, in the current study, finding the types of noise that do not cause an emotional, mental or physical discomfort to the learners and the teachers was important in three ways:

Firstly, Johnson and Christensen, (2012, p.115) and McMillan and Schumacher (2012, p. 131) admonish researchers who conduct their studies in education to comply with ethical considerations and make sure that participants are protected from mental and physical discomfort (see, Section 2.4.2).

Secondly, Tuckman (1988, p.129) recommends that in order to comply with the internal validity, any manipulation done in one intervention group must be done across all intervention groups so that the research environment is similar and constant in all intervention groups. During the administration of the achievement tests across six Grade

10 mathematics classes, the learners first wrote the test in the environment controlled by the SNR device with the noise ranging from 50 to 60 dBA. Thereafter, they wrote the test in a noisy environment with the music amplified to 70 to 80 dBA (Section 4.6.3.3).

Thirdly, Donald (1990, p.306) mentions that the manipulation used to control the research environment must be able to hold the extraneous variables constant meaning that the participants in all groups are treated exactly alike except for the exposure to the independent variable. Since the independent variable in this study is '*noise*', the types of music used, the sequence in which the music were played and the sound level of the music had to fit the working definition of noise which is the "*wrong sound in the wrong place at the wrong time"* (see, Section 1.10.2). Therefore, instead of playing music related to mathematics, number patterns or mathematics mnemonic, local popular music, implying that *wrong sound* is used. In addition, the music was played at *wrong place* because local popular music is not meant to be played in mathematics classroom. Furthermore, the music was played at *wrong time*, because popular music is not meant to be played during the time of mathematics achievement tests. To ensure that the music had elements of disturbing the classroom atmosphere like any type of noise, each music would play for about 15 seconds and the next music would play randomly. In addition, the sound of the music was amplified to 70 – 80 dBA using a portable speaker.

4.4.6 Mathematics achievement tests

Two hundred and five (205) learners from six Grade 10 classes in six schools wrote three types of mathematics achievement tests. namely, algebra test, basic mental and calculation test and a geometry test (see, Table 4.4). Each component of the mathematics achievement tests was designed to assess a certain aspect of learners' cognitive and thinking abilities. For instance, the questions in the algebra test assessed learners' ability in solving mathematics questions with high cognitive level. The questions in the basic mental and calculation test assessed learners' ability to comprehend the task instructions when performing basic mathematics calculations. On the contrary, the questions in the geometry test assessed learners' ability to recall the previously learnt mathematics information and skills, and to perform a mathematical task. The mathematics tests were

administered to the learners by the researcher in the time agreed upon by mathematics classroom teachers and the learners (see, Section 4.6.3.1 & Section 4.6.3.1).

The three mathematics achievement tests were administered to the learners using the A-B experimental design. Since three tests were given to the learners, the A-B experimental design process was repeated three times (as A-B-A-B-A-B design) (see, Section 4.3.3; see, also, Table 4.2*:*). The importance of starting with the baseline is supported by Suter (2012, p. 38, 39) who stated that this procedure constitutes the starting point of the data collection that enables the researcher to monitor and determine over a period of time any influence of the intervention (Suter, 2012, p. 38, 39). McMillan and Schumacher (2012, p. 306) assert that baseline and interventions last the same length of time and consist of the same number of observations. Similarly, every time that the baseline data were collected, the SNR device was switched off and the noise ranged from 70 to 80 dBA. Thereafter, it was followed by an intervention in which the SNR device was installed in the classroom the noise of 50 to 60 dBA.

Data that relates to learners' errors that were made in different mathematics achievement tests on different cognitive levels were used to answer the main research question and the sub-research questions 4, 5 and 6 (see, Section 6.3.2.4, 6.3.2.5 & 6.3.2.6).

4.4.6.1 Algebra test

The first achievement test to be administered to the learners was an algebra test. The Algebra test consisted of three questions of Grade 10 mathematics syllabus. The questions in the algebra test were designed to assess learners' ability in solving mathematics questions with high cognitive level. Questions in the algebra test were administered to the learners by the researcher in the form of printed question papers. Learners would then be expected to complete the test in 15 minutes and write their responses in the answer book that was provided. Questions in algebra test were designed to assess learners' achievements in the following areas:

- ability to follow the procedures in multiplying algebraic expression with accuracy;

- ability to expand and multiply a perfect square binomial with fractions; and
- ability to evaluate and solve two algebraic expressions (see, Appendix A & Table 4.5).

The following questions were included as algebra test items:

1. Simplify: $(m-m)(3m-2mn+4)$

2.1 Simplify.$(m+\frac{1}{m})^2$

2.2 Evaluate $m^2+\frac{1}{m^2}$ if given that $m+\frac{1}{m}=3$

In the administration of the algebra, the researcher handed the question paper along with the answer book to the learners. The researcher informed the learners that the test would be completed in 15 minutes. After 15 minutes the researcher collected the answer sheets from learners. The algebra test was administered to the learners in the classroom with the noise level controlled by the SNR device from 50 to 60 dBA. Thereafter, another algebra test with similar content with the first test was administered to the learners in the classroom noise level ranging from 70 to 80 dBA. To achieve the constant noise level of 70 to 80 dBA, local popular music was also played in the classroom (see, Section 4.4.5 & Section 2.4.2).

4.4.6.2 The basic mental and calculation test

The second achievement test that was administered to the learners was the basic mental and calculation test. The basic mental and calculation test focused on testing learners' listening skills, doing mental calculations using basic mathematics knowledge. The basic mental and calculation test consisted of 10 general numeracy questions, like,

- listening to 9-digit telephone numbers and writing them in the order in which they would be read out;

- multiplication of two single digit numbers;
- arranging three units of measurements from the smallest to the biggest;
- multiplication and division of monomials;
- calculating basic percentages; and
- subtracting two integers of double digits (see, Table 4.6).

The aim of these basic questions was to determine how best do learners hear simple instructions from the mathematics teachers and perform the task accurately in an environment with high level of noise compared to an environment in which the noise is controlled.

In the administration of the basic mental and calculation achievement test, the researcher used the questions in the basic mental and calculation achievement test sheet (Appendix B). The researcher read out one question at a time to the learners. After reading the question, the researcher waited for a period of 30 seconds and thereafter, a new question would be read out. Learners were supposed to provide or write their responses in the answer book that was provided. The basic mental and calculation test was administered to learners in the classroom with the noise level controlled by the SNR device from 50 to 60 dBA. Thereafter, another basic mental and calculation test with similar content with the first test was administered to the learners in the classroom noise level ranging from 70 to 80 dBA. To achieve the constant noise level of 70 to 80 dBA, local popular music was also played in the classroom (see, Section 4.4.5 & Section 2.4.2).

4.4.6.3 The Euclidean geometry tests

The third achievement test that was administered to the learners was the Euclidean geometry test. The Euclidean geometry test consisted of seven questions learners would be able to complete the test in ten minutes. The questions in the geometry achievement tests were designed to assess learners' ability to recall some of Euclidian's reasoning procedures and use these cognitive skills to make certain determinations of angle sizes that the task at hand would require. In this regard, learners were expected to solve basic calculations by finding certain angles in parallel lines, transversal lines and triangles. The

latter included solving supplementary and complementary angles with reasons, solving interior and sums of exterior angles of the triangle with reasons, and solving corresponding and vertical opposite angles with reasons (see, Appendix C & Table 4.7). The content of topics used in the geometry achievement test was for Grade 9 level.

Ahead of administering the achievement test, the researcher explained to the learners that the instructions and the questions would be projected on the screen and that no verbal instructions from the researcher would be given. Given that this study was also concerned about the effect of regulating and minimizing the ECL while learners were solving the geometry problems, the following test administering procedures were considered:

- minimising the number of instructions that would be read while learners were responding to the Grade 9 Euclidean geometry test items; and
- taking the advantage of using the projector to make the geometry shapes in the test bigger.

It was the researcher's belief, which was largely informed by literature, that these test administering procedures would help to regulate and minimise the effect of extraneous variable such as reading difficulty, hearing difficulty, and content difficulty of the achievement test (Halin, Marsh, Hellman, Hellstöm & Sörqvist, 2014).

The initiatives to regulate and control the extraneous variables were meant to make a determination if the variations of noise levels in the classroom would solely have some effects, if any, on the learners' ability to recall efficiently the previously learnt mathematics information, the skills and the effective performing of a mathematical task. The test items were projected on the screen one question at a time to assist learners to see, with a relay period of 90 seconds (one minutes and 30 seconds) and thereafter a new slide would emerge.

Learners used the answer book that was provided to write their test responses. The geometry test was administered to the learners in the classroom with the noise level controlled by the SNR device from 50 to 60 dBA. Thereafter, another geometry test with

a mathematics content that was similar to the first test was administered to the learners in the classroom noise level ranging from 70 to 80 dBA. To achieve the constant noise level of 70 to 80 dBA, the local popular music was also played in the classroom (see, Section 4.4.5 & Section 2.4.2).

4.4.7 Learners' post-test questionnaire

Learners' post-test questionnaire was administered during the main phase of data collection (see, Appendix B_2 & Section 4.5.4.1). The need to administer learners' post-test questionnaire in collecting data was necessitated after the pilot study data analysis. For example, while learners were writing the mathematics achievement tests in the classrooms in which the SNR was in operation, learners generated many correct answers compared to the classroom in which the SNR device was not installed. Conversely, the classroom that used the SNR device learners in classroom that were without the SNR tended to generate many incorrect answers and left many questions unanswered. Even though noise level seemed to be the main factor another tool was needed to the kind of noise that possibly influenced learners' thinking while they were solving mathematical problems. To overcome that limitation the learner post-test questionnaire was developed (see, Appendix B_2). By analysing learners' responses of the post-test questionnaire, the researcher was able to gain insight, and interpret the reasons for the learners' mistakes (see, Section 4.5.4.1).

4.5 DATA COLLECTION PROCEDURES

Data were collected in three phases, namely,

- in the preliminary data collection in School A, which was also referred to as the manufacturing phase (see, Section 4.3.4.1);
- in the pilot study phase in Schools A, B and C; and
- in the main study phase in Schools D, E and F.

Table 4.8 summarises the data collection phases, the procedures used in this process, the instruments used for data collection and the related research question or research objective that was responded to in each of the research procedures.

Table 4.8: The summary of data collection procedures of the study

		PHASES OF DATA COLLECTION		
Data collection procedures	**Instruments used for data collection**	**Related study objectives**	**Second phase of data collection: Related study objectives and research questions**	**Third phase of data collection: Related study objectives and research questions**
Measuring classroom noise (Section 4.5.2.2)	Sound level meter (Section 4.4.3)	Objectives 1.6.1, 1.6.2 &1.6.3	Objectives 1.6.1 & 1.6.4 Sub-research Q.1	Objectives 1.6.1 & 1.6.4 Sub-research Q.1
Recording classroom noise level (see, Section 4.5.2.3)	Lesson observation instruction guidelines (Section 4.4.4)	Objectives 1.6.1, 1.6.2 & 1.6.3	Objective 1.6.4 Sub-research Q.1	Objectives 1.6.1& 1.6.4 Sub-research Q.1
Regulating learners' classroom noise (Section 4.5.2.4)	The SNR device (Section 3.2)		Objective 1.6.4 Sub-research Q.1	Objective 1.6.4 Sub-research Q.1
Recording learners' behaviour (Section 4.5.2.5)	Lesson observation instruction guidelines (see, Section 4.4.4)		Sub-research Q.1 & Q. 6	Sub-research Q.3 & Q. 6
Administering teachers' questionnaires (Section 4.5.2.1)	Teachers' questionnaires (Section 4.4.1)		Sub-research Q.2	Sub-research Q.2
Administering mathematics achievement tests (Section 4.5.2.6)	Mathematics achievement tests (Section 4.4.6)		Sub-research Q.4, Q.5 & Q.6	Sub-research Q.4, Q.5, Q.6 & Hypotheses (Main research Q.)
Administering learners' post-test questionnaire (Section 4.5.4.1)	Learners' post-test questionnaire (Section 4.4.7)			Sub-research Q.2 & Q.5

Section 4.5.1 presents the data collection procedures for the three phases of the study.

4.5.1 Preliminary data collection

The first phase of data collection was the preliminary phase, also known as the manufacturing phase. During this phase, data were collected in School A. The analysis of data collected in this phase was used to respond to the first three objectives of the study (see, Section 1.6). Firstly, the baseline level of the noise in the classroom while the mathematics lessons were running was determined. At the baseline, the researcher collected data related to the noise level in an unobtrusive manner inside the mathematics

classroom using the sound level meter. Thereafter, in a day or two, the Yacker Tracker was fitted in the classroom and the classroom noise level was determined again. At this early stage, the Yacker Tracker was used to determine if the presence of the SNR device in the classroom would influence learners' noise and behaviour. Furthermore, Grade 10 learners were informed that the Yacker Tracker light would generate a red light when the noise exceeded the recommended noise limit. It was a trial and error process during the first stage of the lesson. In the first ten minutes of the lesson, the noise was much higher because of the learners' excitement. Apparently, learners got excited when they realised that the Yacker Tracker was responding to their noise level as it kept generating different coulors. Thereafter, the class settled and the accurate measuring of learners' noise level in each sequence of the lesson was conducted. The preliminary data collection proceeded in accordance with the A-B-A-B research design (see, Section 4.3.2).

Secondly, every time that the researcher visited the classroom with the purpose of recording the classroom noise level, the researcher would observe and record the sequence and the timing of each phase of lesson's activity using the lesson observation instruction guideline (see, Appendix E). The kind of data collected in this regard and the information it generated were used to influence the assembling the SNR prototype (see, Section 3.2). The preliminary data collection activities and the assembling of the SNR prototype took a period of over 12 months. In the period of 12 months, the researcher made several classroom observations while kept returning to the classrooms to measure the noise level while the Grade 10 mathematics lessons were conducted. The research activities in the 12 months were meant to ensure that there would be consistency in the nature of data that was used in the SNR programme so that this tool would function more reliably. The finally constructed SNR prototype was used in second phase of data collection, which constituted the pilot study phase.

4.5.2 Pilot study data collection

It took one year to collect the pilot study data in Schools A, B and C (see, Section 4.3.4.2). The data were meant to respond to all study objectives and all research questions as outlined in Section 1.6 and Section 1.8. In cases where the pilot data succeeded in helping the researcher to achieve the research objectives of the study, and in successfully responding to the research questions, then the collection of these data in the main study would be for the validation purposes. Conversely, when it was observed that the data collected in the pilot study fell short in assisting the researcher to the study objectives and research questions then the process of responding to these would be done in the main study (see, Section 4.5.2 & Section 4.5.4). The limitations of the pilot study phase are discussed in Section 4.5.3. McBride (2016) and Herrington, *et al.* (2007) mentioned that a study that is conducted within an intervention research design framework may have some level of freedom in terms of making adjustments in the methods of the data collections (see, Section 4.2 & Section 2.8).

The following procedures were used to collect data in the pilot study and the main study: administering the teachers' questionnaires, observing mathematics lessons, measuring classroom noise level, and administering the mathematics test to the learners. One of the limitations encountered during the analysis of data in the pilot study was related to the absence of learners' post-test questionnaire, which was later used to provide missing information in the process of analysing learners' noise behaviour in Grade 10 mathematics classrooms. To address this limitation, an additional data collection instrument was introduced in the main phase of data (see, Section 4.5.3). The following sections discuss each method of data collection during the pilot study and the rationale for using them.

4.5.2.1 Administration of teacher questionnaires

Six questionnaires were administered to Grade 10 mathematics teachers during the early data collection phase for the pilot study. This process took place in schools A, B, C (see, Section 4.3.4.2). The teachers' questionnaire consisted of ten close-ended questions related to the noise level in the classroom, outside the classroom and outside the school premises. The questions in the questionnaires had been designed to elicit teachers'

responses in terms of their perceptions and attitudes toward the noise level and their experiences both inside and outside the mathematics classrooms (see, Appendix D). Teachers whose classes were used to participate in the study were asked to use a tick (√) on the provided Likert scale to indicate the extent to which they experienced learners' classroom noise levels during their teaching session of mathematics. Teachers' responses in the pilot study are presented in

Table 5.2. The teacher questionnaire data was used to respond to the sub-research question 2.

4.5.2.2 Measuring classroom noise level

As an integral part of this study, the classroom noise level was constantly recorded using the SLM every time, the researcher visited the mathematics classrooms in Schools A, B and C. In every two minutes, the researcher recorded the instant noise level in dBA units. Each school was visited once a week. Every week the SNR device was alternatively installed in the classroom. This arrangement meant that if in the first week the sound level was taken without the SNR device, the following week the sound level would be taken with the SNR device installed in the classroom. Therefore, the collection of data related to the noise level also proceeded in accordance with the A-B-A-B research design (see, Section 4.3.2). In the pilot study, data related to classroom noise level was used to respond to the research objectives 1.6.1 and 1.6.4, and the sub-research question 1.

4.5.2.3 Recording classroom noise level

In the pilot phase, data related to the noise in the classroom was constantly captured and recorded on the lesson observation instruction guidelines. The researcher used a hand-held SLM (see, Section 4.4.3). The researcher sampled and recorded every instant noise level measurement captured by the every two minutes (see, Figure 5.6; Figure 5.7 & Figure 5.8). While this sampling made it possible to have manageable data to handle and analyse without much difficulties, the researcher noticed that it had some limitations (see, Section 4.5.3). Some important details of learners' noise level in between the two minutes interval could be lost, for example, learners' excitements and laughter that lasted less than a minute could be missed. Also, some external noise factors like the school bell, learners

walking in the school corridors or aeroplane passing by could not be captured and be recorded.

During the analysis of data that had been collected in the pilot study, efforts were made to address the limitation related to the method in which classroom noise level had been captured and recorded (see, Section 4.5.3). The researcher only compared the classroom noise level that was generated at the same time of the day. In addition, the researcher studied different lessons and only compared the classroom noise level where learners were involved in similar activities (see, Figure 5.6; Figure 5.7 & Figure 5.8). Therefore, to increase data validity and to reduce the amount of work involved in sorting and organising data in the main study, data were recorded every two seconds, and was instantly converted into a graph by a computer with a noise level software (see, Figure 5.17; Figure 5.18 &

Figure 5***.19***). In the pilot study, data related to classroom noise level recorded on the lesson observation instruction guidelines were used to respond to the research objectives 1.6.1, 1.6.2 and 1.6.4 and the sub-research question 1.

4.5.2.4 Regulating learners' classroom noise

In the pilot study, the SNR device was used every second week in each of the participating schools, namely, A, B and C. This arrangement was such that one week would be with the SNR device and another week would be without the SNR device in participating schools. This means that in one school if in the first week the sound level measurements were taken without the SNR device, then the following week the sound level measurements would be taken with the SNR device installed in the classroom. This unfolding of research activities in participating schools was in line with the A-B research design (see, Section 4.3.2). In the main study, this sequence of regulating learners' noise was adjusted because the researcher had identified some of the limitations when analysing data in the pilot study (see, Section 4.5.3). In the main study, the researcher decided to change the time interval in which A-B design was used to regulate learners' classroom noise level using the SNR. Instead of using one day a week with the SNR device and using another day the next week without the SNR device or vice versa, the researcher opted to use the first half session of the lesson without the SNR device and the second half of the same lesson with the SNR device. In the pilot study, data related to the use of the SNR device in regulating learners' classroom noise level helped the study to respond to the research objective 1.6.4 and the sub-research question 1.

The SNR device was used when the mathematics achievement tests were administered. Whenever the classroom noise level needed to be regulated, the SNR device was used, and the sound meter monitored that the noise was ranging from 50 to 60 dBA. During the tests, whenever the classroom noise level needed to be within the ranges of 70 to 80 dBA, the local and popular songs were played amplified from 70 to 80 dBA and were monitored by the SLM (see, Section 4.4.5 , Section 2.4.2 & Section 5.4.3). In the pilot study the data related to learners' performance in different mathematics tests when the SNR device were

used compared to their performance when the SNR device was not used, contributed to respond to the main research question and the sub-research questions 4, 5 and 6.

4.5.2.5 Mathematics lessons observations

In the pilot study, the observation of Grade 10 mathematics lessons formed part of data collection and the analysis of this data assisted in validating the data collected in the preliminary stage relating to the timing and sequencing of different activities in the mathematics lesson (see, Section 5.3.1). The researcher observed and documented the duration of the time of each activity in a mathematics lesson with the SNR device in operation to see if it was user-friendly for a mathematics teacher; and, (2) in observing and recording learners who were engaged, focused and listening to the teacher's instruction during the lesson (see, Section 4.4.4). This type of data was collected using the lesson observation instruction guidelines (Appendix E) and took place once a week for each in the three schools for the duration of one year.

4.5.2.6 Administration of mathematics achievement tests to the learners

Halin, *et al.* (2014) used a reading experimental study by manipulating learners' background noise. The study explored the relationship between noise, task difficulty, distraction, and the working memory capacity. The study used different tests in reading within various stimulated and enhanced noise environment, which resembled that of day-to-day reading session. Learners' level of concentration and distractibility were studied. The study used a manipulation of task difficulty against the distraction that was caused by the noise level to determine if there was a relationship between noise, task difficulty, distraction, and the working memory capacity. The study participants would first read the text in a quiet environment and thereafter in an environment that had the background noise. The texts that were displayed were either in an easy-to-read or in a hard-to-read font. The study concluded that background noise had a way of weakening the memory or the recalling of the written prose recall in reading (Halin, *et al.*, 2014). This study performed experiments like those of Halin, *et al.* (2014) to determine the extent to which learners' noise level affected their accuracy, their motivation to attempt questions and their overall performance in mathematics.

Learners wrote the mathematics achievement tests in a classroom with a noise environment ranging from 70 to 80 dBA. Thereafter, the SNR device was used and the sound meter monitored that the noise was ranging from 50 to 60 dBA. Participants wrote three types of tests and the answer sheet was provided during the test. The researcher analysed and documented errors that were made by learners during the tests in the baseline and at the interventions' experiments. Data generated from the experiments using the A-B research design were compared and statistically analysed to determine the extent to which the SNR influenced learners' performance in the audio, visual and written mathematics achievement tests (see, Section 4.4.6). In the pilot study, the data related to learners' performance in different mathematics tests were used to respond to the main research question and the sub-research questions 4, 5 and 6.

4.5.3 Study limitations of the pilot study

The pilot study revealed some of the limitations. The researcher felt that the limitations in pilot study did not constitute a serious threat to the internal validity of the study. However, the researcher felt that it was necessary to address these limitations in the main study in order to strengthen the internal validity and to overcome obstacles that could show themselves during the data analysis process. The limitations in the pilot study were related to:

- the sequence in which the mathematics achievement tests were administered in the pilot study;
- the fact that the learners' post-test questionnaire was not administered in the pilot study;
- the methods of capturing the classroom noise level as well as their recording in the pilot study; and
- the sequence of recording learners' classroom noise in the pilot study.

The first limitation is related to the sequence in which the mathematics achievement tests were administered in the pilot study. During the pilot study, the researcher used 10 to 15 minutes at the end of the lesson to administer the mathematics achievement tests to the learners. This arrangement seemed to elongate the time at which the mathematics achievement tests were administered to the learners. The researcher and teachers initially considered this arrangement to allow minimum interference to the time allocated to teaching and learning as required by GDE. In practice, the researcher and the teachers noticed that using the portion of the lesson for research purposes was actually interfering with many teaching and learning sessions.

In one instance, School A did not participate in the basic and mental calculations tests (see Table 4.1). This was caused by the fact that by the time the mental calculations achievement test was to be administered, teachers at the school were not teaching owing to teachers' strike. At this stage, the GDE permission was expected to expire the following

week. It was not possible for the same group to write the test in the following year because it was another group of learners, and the study could have threats relating to the internal validity because of history, maturation, testing, and possible attrition. To overcome this limitation in the main study the researcher requested for only between 40 and 80 minutes, which was a period of double mathematics lesson, to administer all the achievement tests to the learners including the learners' post-test questionnaires. The advantages of using just one period of between 40 to 80 minutes instead of 10 to 15 minutes in four weeks to administer all the mathematics achievement tests was that it was less inconvenient to the teacher and the researcher.

The second limitation was related to the fact that the post-test questionnaire was not administered in the pilot study. During the analysis of data from the mathematics achievement tests, the researcher encountered a challenge. In the classrooms with the SNR in operation, the analysis of data revealed that learners were able to produce many correct answers compared to the classroom without the SNR device. Conversely, in the classroom without the SNR device, learners produced many incorrect answers and left many questions, and many did not attempt to solve problems in the test. The researcher wondered if these errors were because of the noise factors only, and wanted to explore the phenomenological thinking that caused learners to make so many errors. In the main study, the researcher asked the participating teachers to suggest examples of short questions that may be asked to their learners and revealed what they have experienced by writing the mathematics achievement tests in classroom environment with music. In developing learners' post-test questionnaire, the researcher also used the questions in a study that explored the impact of earphones on learners (Harshitha & Siddiqua, 2017) (see, Appendix B_2). By completing a post-test survey, the researcher was able to understand and interpret the mistakes made by learners during the mathematics achievement tests (see, Section 4.5.4.1).

The third limitation was related to the method in which classroom noise level was recorded. During the pilot phase of data collection, data related to the noise in the classroom was constantly captured and recorded on the lesson observation instruction

guidelines. The researcher used a hand-held sound level meter. The researcher sampled and recorded every instant noise level measurement captured by the sound level meter every two minutes (see, Figure 5.6; see, also, Figure 5.7 & Figure 5.8). Some important details of learners' noise level in between the two minutes interval could be lost, for example, learners' excitement and laughter that would last less than a minute could be missed. In addition, some external noise factors like the school bell, learners walking in the school corridors or aeroplane passing by could not be captured and be recorded. To overcome the limitation related to the method in which classroom noise level was recorded, in the main study the researcher opted to use a computer noise level software. The computer noise level software was able to instantly record the classroom noise level every two seconds, which eliminated some threat to validity related to instrumentation.

The fourth limitation was related to the sequence used to record learners' classroom noise. During the pilot study, the SNR device was used every second week in each of the participating schools. This means that in one school, if the first week the sound level measurements were taken without the SNR device, the following week the sound level measurements would be taken with the SNR device installed in the classroom. This arrangement of leaving an interval of one week between the first test and the second test seemed to have presented other nuisance variables that constrained the accurate interpretation of the effects of the SNR device in controlling the noise level in mathematics classrooms.

The researcher noticed that the average learners' noise levels in the classroom depended on the time of the day on which the mathematics lesson took place. In the morning, the learners seemed to keep their noise level under control, but after the break or lunch time learners seemed to increase their noise level. Pope (2016) explained one possible explanation of this phenomenon. Pope (2016) found that in the morning, learners in Grade 9 to 11 are more productive and engaged in their classroom learning than in afternoon. Furthermore, the classroom noise level seemed to be influenced by the mathematics topics that learners were being taught. In the topics that learners found to be more challenging, the noise level escalated compared to topics that were less challenging to the learners. The researcher realised that factors related to the variations of the average

noise level in the classroom, like the causes of learners' classroom level relative to the time of the day and learners' classroom level relative to the difficulty of the topic in mathematics, could require another extended study. However, another extended study could have derailed the objectives of the current study. The researcher realised that it was possible to control the causes of different noise level variations by comparing the noise level data that was collected on the same day. Therefore, in the main study, the researcher decided to reduce the interval between the first test and the second in which the A-B design was used to determine the effects of the SNR device in controlling the noise. Instead of using one day a week with the SNR device and use another day the next week without the SNR device, the researcher opted to use one whole lesson with and without the SNR. This meant that for the first part of the lesson, the SNR device would be used and for the second part of the lesson, the SNR device would to be switched off.

4.5.4 The collection of data in the main study

During the third phase, the researcher collected data for the main study in schools D, E and F for the duration of one year (see, Section 5.4). The duration of one year allowed the researcher to observe many lessons and to use the SNR device in lessons that occurred in different times and days. The main study data collection stages were carried out according to the same procedures that were used for the pilot study data collection (see, Section 4.5.2). During the pilot study, the researcher noted that there were minor limitations that could have affected the internal validity and the interpretation of the findings. The researcher felt that it was necessary to address these limitations. These limitations were related to, (i) the sequence in which the mathematics achievement tests were administered in the pilot study; (ii) the absence of learners' after-test questionnaire in the pilot study; (iii) the method in which classroom noise level was captured and recorded in the pilot study; and, (iv) the sequence of recording learners' classroom noise in the pilot study (see, Section 4.5.3). The limitations were addressed during the main study phase of data collection.

4.5.4.1 Learners' post-test questionnaire data collection

After the analysis of the pilot study data of learners' mathematics achievement tests it was necessary to administer the learners' post-test questionnaire (see, Section 4.4.7). The researcher realised that the absence of learners' post-test questionnaire would pose some limitations. For instance, without learners' survey there was a challenge to make a determination if there were other confounding variables such as boredom, fatigue and stress that were possibly influencing learners' performance in the mathematics achievement tests. In addition, even if the excessive noise level was the influencing variable, the researcher needed to know related inconveniences that learners possibly faced when solving mathematics achievement tests in an environment with an excessive classroom noise level. Learners were asked to use a tick (✓) to indicate the phase that represented their experience during each mathematics test. Every time that a test was written in a noise environment of 70 to 80 dBA, learners immediately completed a post-test questionnaire. Therefore, learners' experiences and feelings were captured instantaneously.

4.6 VALIDITY AND RELIABILITY OF THE DATA COLLECTION INSTRUMENTS

To insure the trustworthiness of an empirical research study, the research design and the instruments used to collect data need to elicit the most relevant, reliable and valid data. Therefore, this section presents the steps that were followed by the researcher in ensuring that the instruments used were reliable, valid and that the process used to collect data was scientifically credible.

4.6.1 Reliability

Reliability refers to two aspects, namely, the consistency of the collected data and the repeatability of the same data when collected from other participants with similar characteristics. Reliable instruments provide stable results regardless of the place and the time interval of data collection (Johnson & Christensen, 2012, p. 138). Gay, Mills and Airasain (2011, p. 301) identified a common threat to reliability in a single-case experimental design as instrumentation, the unreliability or inconsistency of measuring instruments. To overcome the threats to reliability, this study used the following methods:

Test-retest reliability of mathematics achievement tests, expert and peer review of questionnaires and a sheet for learners' classroom behaviour.

4.6.1.1 Test-retest reliability of mathematics achievement tests

This study used a test-retest procedure to measure the reliability of the instruments used to measure classroom noise level and learners' mathematics tests. Johnson and Christensen (2012, p. 139) point out that the test-retest reliability measures the consistency of scores over time. In the same vein, Tuckman (1988, p. 172) also concurs that test-retest reliability measures the degree of correlation to which tests results are consistent when the same test is given to respondents on two separate occasions. During the preliminary phase, all instruments were developed and tried in one Grade 10 mathematics class. Mathematics achievement tests were administered to the learners in School A on two separate occasions, and the correlation coefficient of each of the mathematics test was determined. A further correlation coefficient of each mathematics test results was performed between learners in two schools in a similar setting. Table 4.7 shows the test-retest reliability coefficient in School A and across schools with the same settings. The rational of using the test-retest was to measure the reliability for schools in the same setting was to determine if learners' performance was the same for generalisation purposes. The interpretations of the test-retest reliability coefficient were taken from McMillan and Schumacher (2014, p. 195).

Table 4.9: Test-retest reliability between schools

School Code	Characteristics of the school	Type of mathematics Test	Test-retest reliability coefficient	Interpretation
A&D	School located in the city/ the suburb	Algebra test	0.9387	Excellent
		Geometry test	0.9840	Excellent
B&E	Among the old building (over 100 years old)	Algebra test	0.9154	Excellent
		Basic Mathematic test	0.9626	Excellent
		Geometry test	0.9376	Excellent
C&F	Close to the railway line	Algebra test	0.7530	Acceptable
		Basic Mathematic test	0.9336	Excellent
		Geometry test	0.9378	Excellent

The test-retest reliability coefficients indicate that they ranged from acceptable to excellent, which indicates that the mathematics achievement tests passed the reliability test.

4.6.1.2 Achieving reliability in administering the questionnaires

The researcher contacted his mathematics colleagues in secondary schools to get their views on the inclusion of ten items in the teacher questionnaire. The ten items were in the form of questions related to noise level types inside the classroom, the effects that noise level had on their teaching and health, and the main sources of noise. The researcher reviewed the different questions from the colleagues and developed ten questions for the questionnaire with Likert scale ratings. The questionnaire was sent back to the colleagues or reviewers to check if there was a level of bias in the formulation of questions. Minor alterations were made.

Learners' post-test questionnaires were subject to the same reliability measures as the teacher questionnaire. The only exception in ensuring the reliability of learners' post-test questionnaires was that the teachers of classes that participated in the study were those that were involved in the process of ensuring reliability for the learners' post-test questionnaires. The need to include learners' post-test survey emerged after the pilot study data analysis. Mathematics achievement tests in the classrooms with the SNR in operation learners produced many correct answers compared to the classroom without the SNR device. The researcher also invited mathematics teachers of classes that participated in the study to contribute on items questions to be included on the learners' post-test questionnaires. The questions in the learners' post-test questionnaires resembled like the questionnaires used to assess the impact of music on learners' performance in mathematics (Harshitha & Siddiqua, 2017). The questions in the questionnaire were designed to understand the difficulties that learners encountered when writing mathematics achievement tests with a noise level condition ranging between 70 and 80 dBA.

4.6.1.3 Reliability of learners' classroom behaviour sheet

A list of items of learners' behaviour related to noise level inside mathematics classroom were determined by means of three different studies:

- the Algozzine (2012) list of learners' classroom inappropriate behaviour;
- the Ofsted (2014) list of inappropriate classroom behaviour; and
- the list of disruptive and off-task behaviour, compiled by Hagoramagara (2015).

Eight items related to learners' disruptive behaviours and seven items related to learners' off-task behaviours that appear prominently in all the three studies were used in the learners' classroom behaviour sheet that was used for class observation

4.6.2 Validity of instruments

According to Taherdoost (2016), validity explains how well the collected data covers the actual area of investigation. In addition, Donald (1990, p. 256) avers that validity is concerned with the extent to which an instrument measures what one intends to be measuring. Gay, *et al.* (2011, p. 301) posit that a common threat to validity in a single-case experimental design could be associate with the instrumentation process, researchers' own perception and biases, and controlling extraneous and confounding variables. Therefore, the following section discusses types of validity measures that ensured that the instruments and processes used in this study were valid.

4.6.2.1 Content validity of mathematics achievement tests

Tuckman (1988, p.176) asserts that a test with appropriate content validity enables the researcher to determine how an individual would function in a set of actual situations. The study used three sets of mathematics achievement tests that were administered to learners. The tests were meant to assess how learners performed in a classroom environment that was controlled by the SNR device, with a noise level ranging between 50 and 60 dBA, compared to a classroom environment without the SNR device, with a noise level ranging between 70 and 80 dBA. Content validity for the mathematics achievement tests was highly required.

According to Donald (1990, p. 258), to ensure the content validity of the tests, one should determine if the items in the tests represent the course and objectives as stated in the curriculum. To obtain an external evaluation of content validity, the test maker should ask a number of teachers or other experts to examine the test content and to evaluate its relevancy to the research question. If the experts agree that the test items represent the contain domain adequately, the test can be said to have content validity.

The contents of the mathematics achievement tests were from the GDE, which means that these tests have undergone moderation processes by the GDE and have passed the DBE assessment guidelines (DBE, 2010). In this study, three mathematics achievement tests have undergone mathematics expert scrutiny in checking the content. Six mathematics teachers who participated in the study were experts in Grade 10 mathematics content. Teachers were given the test to validate the content and they unanimously agreed on its relevance and Grade 10 level appropriateness. Donald (1990, p. 258) highlights that for “the test to be valid, it should be free from the influence of factors that are irrelevant to the purpose of the measurements. For example, performance on a mathematics test should not be influenced by reading speed and vocabulary. The presence of these factors in a mathematics test would lower its validity because the test would be measuring something else than what it intended to measure”. The questions in each mathematics achievement test (Algebra, Basic Mathematics Calculations and Geometry) were designed with instructions that were simple to read. In the geometry test, the projector’s screen resolution was 150cm by 150cm, which was big enough for every learner to see. Table 4.8 shows the content, skills and expected outcome for each question in the mathematics achievement tests.

Table 4.10: The content of mathematics achievement tests

Content and skills required	Means of administrating the tests	Question numbers	Knowledge assessed
Algebra test: Following procedures and rules. Evaluation and problem solving.	Questions were administered to the learners in the form of printed question papers. Learners were to answer in the answer book provided.	**1**	Following procedures in multiplying algebraic expression with accuracy.
		2.1	Expanding and multiplying a perfect square binomial with fractions.
		2.2	Evaluating and solving two algebraic expressions.
Mental mathematics test: Listening skills, retrieving the and using basic mathematics knowledge	The questions were read out for learners to answer in the answer book provided.	**1&3**	Listening
		2&4	Basic knowledge in multiplication
		5	Arranging units of measurements
		6&7	Multiplication and division of monomials
		8&9	Calculating basic percentages
		10	Evaluating integers
Geometry: Using their vision, remembering the reasons.	The questions were projected on the screen for learners to see and answer in the answer book provided.	**1&2**	Solving supplementary and complementary angles with reasons.
		3,4&5	Solving interior and sums of exterior angles of the triangle with reasons.
		6&7	Solving corresponding and vertical opposite angles with reasons.

4.6.2.2 Content validity of teacher questionnaire

Six teachers' questionnaires were administered during the early stages of the data collection phase for the pilot study and the main study. The advantages of administering questionnaires to the teachers during the early stage of data collection were that teachers became more aware of the prevalence and effects of the noise level during their mathematics lessons and that they willingly accepted to be used as part of the study, in line with Goff and Getenet (2017) (see, Section 4.4.1). The teacher questionnaire consisted of ten close-ended questions.

Question 1, 2 and 3 of a questionnaire focused on the extent to which teachers experienced learners' inappropriate behaviour caused by classroom noise. Questions 4 and 5 focused on the effects of the noise level on the mathematics lesson delivery. Questions 6, 7, 8, and 9 focussed on the teachers' perception of the source of the noise level inside, outside the classroom and outside the school premises. Question 10 was designed to provide understanding of the extent to which the learners complained about

the noise level in the classroom. In general, the questions in the questionnaires were designed to elicit responses from Grade 10 mathematics teachers about their perceptions and attitudes toward the noise level and their experiences both inside and outside mathematics classrooms in the South African context.

4.6.2.3 Concurrent validity of the SNR device

According to Zheng and De Jong (2011, p. 2), concurrent validity is a degree to which the results from one instrument agree with the results from other instrument that measures the same or similar constructs. Concurrent validity was used to ensure that the noise level captured by the SNR device in the mathematics classroom was as accurate as possible. In line with the concurrent validity every time that the SNR device was used in the classroom, a sound level meter with an accurate factory calibration was used alongside with the SNR device. The noise level met the specifications required by the South African Act's 'noise control regulations in terms of section 25 of the Environmental Conservation Act 1989 (Act No. 73 of 1989). The Act recommends that the microphone of the noise level metre be fitted with a windshield that is calibrated for accuracy and operated in accordance with the manufacturer's instructions (ibid). Concurrent validity was used to account for the accurate emission of colours by the SNR device, that is, sending out the correct warning signal, in terms of colours, during mathematics lessons. The colour signals emitted by the SNR device to reflect on the specific level of classroom noise were synchronised with the colour signals of classroom noise level of the Yacker Tracker.

4.6.2.4 Construct validity of the post-test learner questionnaire

McMillan and Schumacher (2014) define construct validity as a type of an experimental validity that refers to the extent to which a study represents the underlying construct. In this study, the assessment of the construct validity of the learner's post-test questionnaire was necessary in measuring the ECL, which is a construct. Donald (1990, p. 261-262) explains that while a construct or psychological trait cannot be measured directly, much of the behaviour that we believe to be aspects of this construct can be described and measured, and the sum of these measures can yield an indirect measure of the abstract construct. ECL is construct but it can be defined in terms of its effects on learners'

processing of learning as discussed in Section 2.5.3. Woolfolk (2013, p. 306), Schenck (2011, p. 231) and Slavin (2007) that ECL negatively affects learners' remembering, storing and retrieval of knowledge. Therefore, the ECL may cause learners to forget the procedures for problem solving in mathematics. In turn, this may reduce the time it takes a learner to perform the task effectively.

Based on the behaviour associated with the effects of the ECL, the researcher developed a short learner post-test questionnaire to assess the extent to which excessive noise level in the mathematics classroom exerts a measure of ECL on learners. The questionnaire was administered to learners after they had written each of the three mathematics achievement tests in a noisy learning environment with a noise level between 70 and 80 dBA. Learners were asked to tick (✓) on the questionnaire one of the six expressions that represented their experience during their mathematics test in a noise-induced environment. The options in the questionnaire were, *It was confusing*; *I needed more time*; *I felt happy*; *I felt normal*; *I did not feel happy*; and *other* (see, Appendix A_3). In case a learner ticked (✓) "*other*", the learner was asked to write down the kind of feeling, which could have not been indicated in the questionnaire.

4.6.3 Internal validity

McMillan and Schumacher (2014) define internal validity as the degree to which the extraneous variables and confounding variables may be controlled. In addition, internal validity addresses the issues of how the researcher dealt with the issue of bias in collecting and analysing the data. In administering the mathematics achievement tests to the learners, the study followed the A-B-A-B single research design. The procedures of collecting data using the A-B-A-B single research design are similar to those of the one-group pre-test – post-test design (Johnson & Christensen, 2012, p. 250). Like the one-group pre-test – post-test design, the A-B-A-B single research design has a stage at which the pre-test is administered first, then followed by a treatment and concluded with the post-test measure (Johnson & Christensen, 2012, p. 334). Therefore, the following section explains how the threats to the internal validity were addressed.

4.6.3.1 Internal validity: time interval

Fellows and Liu (2015, p. 147) and McMillan and Schumacher (2014, p. 285) identified the threats to the internal validity that may be associated with the length of time between the pre-test and the post-test, namely, history, maturation, testing, and attrition. During the pilot study, the researcher anticipated that these types of threat to internal validity could play themselves out in the study. In the pilot study, there was an interval of about two weeks between the time of measuring the first noise level without the SNR and the time of measuring the second noise level with the SNR device installed in the classroom (see, Sections 5.3.3.1, 5.3.3.2 & 5.3.3.3). In the main study, these potential threats to internal validity were addressed effectively because the noise level was taken during one lesson only. In addition, in the main study the mathematics achievement tests were administered on the same day in different noise level classroom environments.

In the pilot study, data were recorded in over two different days. For the main study, data of classroom noise level with and without the SNR device was captured in the same lesson. The SNR device was installed in the classroom for the first part of the lesson. About halfway during the lesson the SNR device would be switched off. Alternatively, if during the first part of the lesson there was no SNR device in the classroom, about halfway during the lesson the SNR device would be installed (see, Section 5.4.2). During the main study, the perceived potential threats to the internal validity, that could be related to history, maturation, testing, and attrition were eliminated. The researcher felt that some level of the carry over effect could have influenced the participants. Particularly, the second test was written immediately after the first one. However, the researcher feels that this carry over effect was kept to a minimum because no corrections followed the first test. Learners were also not given an opportunity to discuss their answers. In addition, the sets of questions in two tests were similar in content but not exactly the same.

4.6.3.2 Internal validity associated with the instrumentation process

Another potential threat to internal validity that was controlled during the study is instrumentation. Johnson and Christensen (2012, p. 252) explain instrumentation as any change that occurs because of the way the independent variable is measured.

Furthermore, McMillan and Schumacher (2014, p. 285) describe the threat to internal validity of instrumentation as the effects on producing different results owing to the unreliability and changes in measuring instruments. In using the sound level meter to capture the noise level inside the classroom, the researcher adhered closely to the South African Act's noise control regulations in terms of section 25 of the Environmental Conservation Act 1989 (Act No. 73 of 1989). The Act recommends that the noise level metre be positioned at a height of between 1,2 and 1,4 metres from the floor and at least 1,2 metres away from the wall (Act No. 73 of 1989). These guidelines were closely followed. During the pilot phase of data collection related to the noise level data collection in the classroom, the researcher would sit at the back of the classroom about 1,5 meters away from the wall. He held the sound level meter with the left hand at the height of 1,2 meters, and manually record instant noise every two minutes, using the right hand.

The researcher made some improvements in the main study to strengthen the internal validity of the instrumentation process further. Fidêncio, *et al.* (2014) reviewed several studies on the level of noise in schools in many countries and found some inconsistencies in the way in which data were captured and recorded. Fidêncio, *et al.* (2014) recommended the use of the noise level software and a computer program connected to the sound level meter to assist in the standardisation of capturing and recording data related to noise level. In accordance with Fidêncio, *et al.* (2014), for recording noise level in the main study, the researcher used noise level computer software instead of recording the data manually.

The use of the noise level computer software strengthens the instrumentation's internal validity because the instant noise level in dBA is captured every two seconds and instantly changed into a graph. In this study, the use of the noise level software and the recording of the instant noise every two seconds enhanced the data internal validity and reduced recording errors that may have resulted from manual recording (see, Section 5.4.2).

4.6.3.3 Internal validity: John Henry effect

According to Welman and Kruger (2004, p. 108), the John Henry effect refers to the effect that occurs when the members of the control group, aware of the fact that their performance will be eventually compared with that of experimental group, exert an extra effort and consequently perform better than expected. The John Henry effect as a threat to internal validity was name after a man 'John Henry' who was a worker that outperformed a machine under an experimental setting being aware that his performance was compared to that of a machine (Welman & Kruger, 2004, p. 108).

The study did not use a control group and an experimental group during the second session of administering the mathematics achievement tests when the noise level in the form of music was introduced in the classroom. Nevertheless, the participants realised that their results with the noise level would be compared to their results in the first test when the noise was controlled by the SNR device. As in the John Henry case, participants were motivated to prove that they could still perform better in a noise level, particularly if the noise level was a form of music. In this study, the John Henry effect, instead of being a threat to validity, served as a means to eliminate the confounding and extraneous variables like boredom, fatigue and stress, which could have resulted in introducing any other type of noise.

4.6.3.4 Internal validity during classroom observations

The presence of the researcher, while observing classroom behaviour and taking the measurements of the noise level in the classroom, was done as unobtrusively to the lesson as possible. The researcher would take a seat at the back of the class before the lesson started. While the researcher visited the mathematics classroom with the purpose of observing the lesson and measuring the classroom noise level, the role of the researcher was that of a neutral and non-participating observer. When the researcher visited the mathematics classroom with the purpose of using the SNR device to regulate classroom noise level, the researcher would only stand up and move around if there was a need to switch the SNR device on and off.

4.6.4 External validity

McMillan and Schumacher (2014) define external validity as the extent to which the results of the study can be generalised to other subjects, condition and situations. The study used three types of external validity: Replication validity, ecological validity and temporal validity.

4.6.4.1 Replication logic validity

Replication logic validity is a form of the main external validity that guided this study. According to Johnson and Christensen (2012, p. 271), experts concur that replication is one way to generalise the findings of studies, even beyond the people in the original study. According to replication logic, the more times a research finding is shown to be true with different sets of people, the more confidence people would place in the findings, and in concluding that the findings may be generalised to a broader population. Also, Johnson and Christensen (2012, p. 21) point out that in the replication of the study, that the researcher examines the same variables with different people. The current study conducted several replications during the data collection phase. There were several episodes of data collection that characterised the research activities in the current study, namely, during the preliminary, in the pilot study and in the main study. Therefore, data collection sessions were repetitive and lasted for three years.

4.6.4.2 Ecological validity

Johnson and Christensen (2012, p. 259) explain that ecological validity refers to the ability to generalise the results of the study across the settings. This study aimed to generalise the findings in three different settings, namely, in schools near the railways, in schools within metropolitan suburbs or inner cities, and in schools located in old buildings that were 100 years and more. The need to address the ecological validity was largely informed by literature. Different studies have focused on the effects of noise level on schools and these studies have been positioned in three settings. (see, Kristiansen *et al*., (2011), in Denmark; Shield, Greenland & Dockrell, (2010), in United Kingdom; Golmohammadi *et al*., (2010), in Iran; Mohan & Rajagopal, (2010), in India; Zannin & Zwirtes, (2009), in Brazil; Zannin *et al*., (2008), in Brazil; Sato & Bradley, (2008), in the USA; Lundquist *et al*., (2003), in Sweden; Chan *et al*., (2015); WHO, (2018).

These studies have emphasised that the noise level in schools near the railways, schools built within the inner metropolitan cities and suburbs, and schools located in old buildings was a major concern to teaching and learning. In developing the SNR device, and in conducting empirical study aiming to mitigate the effects of noise level in mathematics classroom, the researcher positioned the study in the mentioned settings. Sampling techniques were also conducted in three clusters to cater for the three settings (see, Section 4.3.1).

4.6.4.3 Temporal validity

Johnson and Christensen (2012, p. 260) explain that temporal validity refers to the extent to which the study results can generalise the findings across time. Johnson and Christensen (2012, p. 260) also mention that the temporal validity was becoming an important issue in educational research because findings can be valid at one point in time or become invariant over time. This type of validity was necessary in this study because the effectiveness of the SNR device needs to stand the test of time for a period of not less than one year. The SNR device needed to be tested in the classroom with learners for the whole academic year so that its effectiveness could be assessed across all topics of Grade 10 mathematics.

In compliance with the temporal validity, the study was conducted for three years. The first year focused on collecting data at a preliminary stage and on the assembling process for the SNR device prototype. The second year focused on collecting data in the pilot study verification and validating the functionalities of the SNR device. The third year focused on collecting data for the main study, using the final tested features of the SNR device. The SNR device has maintained its reliability for the duration of the research. In addition, the results of the study related to the noise level have remained consistent over the entire study period. Based on the duration of the study and the stability of the finding for a period of three years, it is therefore safe to conclude that the study has maintained temporal validity.

4.7 METHOD OF DATA ANALYSIS

This study followed a mixed methods research design implying that a combination of quantitative and qualitative data is used to answer the research questions (Section 4.3). For data analysis, this study used the qualitative descriptive and quantitative descriptive with inferential statistics. Descriptive qualitative was used to describe the phenomenon involving the changes of learners' disruptive behaviour in the mathematics lessons, in the classroom fitted with the SNR device in comparison of classroom that had no SNR device fitted. In addition, descriptive qualitative was also used to analyse questionnaire data related to teachers' perceptions of classroom noise level on their teaching practice. Descriptive qualitative was used again to capture and to describe learners' experiences after writing tests in an environment where the noise level was ranging from 70 dBA to 80 dBA.

According to the quantitative method, descriptive statistics are used to determine the mean and standard deviation of the recorded noise level. In analysing data related to learners' errors in different mathematics tests, descriptive statistics with mean and standard deviation was used. In contrast, inferential statistics was used to determine the relationship between the mean average of the number of correct answers, the number of incorrect answers and the number of no answers or no attempt of learner's mathematics tests. These relationships and the ANOVA test were used to respond to the formulated hypotheses and to answer the sub-questions.

4.7.1 Descriptive qualitative analysis of learners' inappropriate behaviour

Data related to the incidences of learners' disruptive and off-task behaviour were observed in mathematics classrooms fitted with the SNR device and in mathematics classrooms without the SNR device. The inappropriate incidences related to learners' behaviour in mathematics classroom were recorded in the lesson observation instruction guideline (Section 4.4.4). Data pertaining to the number of incidences in each classroom were organised and tallied in the frequency table. The researcher relied on these notes and the frequency table to describing the effects of the SNR device on learners'

inappropriate behaviour (see, Section 5.3.3.1; Section 5.3.3.3; Section 5.4.2.2; Section 5.4.2.1).

4.7.2 Descriptive qualitative analysis of teacher questionnaires

Data collected from mathematics teachers by means of questionnaires analysed the mean and frequencies of the number of responses using a descriptive qualitative method.

Table 4.11: Likert scale ratings and the interpretation of the scale values

Maximum code range	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Response type	Always	Very frequently	Frequently	Occasionally	Rarely	Very rarely	Never
Interval Likert scale range	$6 < r \leq 7$	$5 < r \leq 6$	$4 < r \leq 5$	$3 < r \leq 4$	$2 < r \leq 3$	$1 < r \leq 2$	$0 < r \leq 1$
Scale range in percentages	$86 - 100\%$	$71 - < 86\%$	$57 - < 71\%$	$42 - < 57\%$	$29 - < 42\%$	$14 - < 29\%$	$0 - < 14\%$

The total responses of teachers in each item of the questionnaire were tallied together using the maximum code range. Thereafter, the mean response per question or item was determined. The researcher used the interval Likert scale range and the mean response per question to determine the extent to which teachers perceived or experienced the noise level in their teaching practice. The interval Likert scale range were converted into percentages so that data related teachers' responses can be easily understood in terms of percentages (see, Section 6.3.2.2).

4.7.3 Descriptive qualitative analysis of learners' post-test questionnaire

Data collected from the learners by means of post-test questionnaire was analysed using descriptive qualitative. The purpose of the survey was to understand learners' experiences when writing different mathematics achievement tests in noisier environment. Learners were asked to use a tick (✓) below the correct phase that represented their experience during each mathematics test written in the classroom noise level ranging from 70 to 80 dBA. Table 4. shows a copy of the learner post-test questionnaire.

Table 4.7: Learner post -test questionnaire

I felt that it was confusing	I felt I needed more time	I felt happy	I felt normal	I did not feel happy	Others

Learners with similar responses were tallied together and analysed using frequencies and simple percentages. Data related to learners' experiences in the post-test questionnaire were analysed per topic and grouped into themes. First, learners' experiences in algebra test were analysed, similar themes were grouped together per school and presented on the bar graph (see, Section 5.4.3.4.1). Secondly, learners' experiences in the basic mental calculations test were also analysed, similar themes were grouped together per school and presented on its own bar graph (see, Section 5.4.3.4.2). Thirdly, learners' experiences in the Euclidean geometry test were analysed, similar themes were grouped together per school, and presented on its own bar graph (see, Section 5.4.3.4.3). Finally, learners' experiences in the post-test questionnaire in algebra, Euclidean geometry and basic mental calculations from all schools were combined together, learners' experiences in similar themes were grouped together and were presented on the bar (see, Section 5.4.3.4.2 & Figure 5.32).

4.7.4 Descriptive statistics data analysis of classroom noise level

Data related to the noise level were analysed using a quantitative method. It used the descriptive statistics to compute the mean and the standard of deviation. The data for preliminary phase were collected in School A only for a period of three months. The researcher sought to know the acceptable noise range for each of five phases of a mathematics lesson. In determining the acceptable noise range for each phase of mathematics lesson, the researcher recorded the minimum, instant and maximum classroom noise level every two minutes. The mean average dBA of the minimum, instant and maximum per phase per lesson was calculated on daily basis. At the end of three

months, the daily averages noise level in dBA per phase were added together and the grand mean was determined.

Data related to classroom noise level of each phase of mathematics lesson are presented as a line graph with an interval of two minutes (see, Section 5.2). In pilot study data analysis, the researcher only compared the noise level of the classrooms that took place on the same time of the day, for an example on the Monday lesson. The researcher would on the first visit take the reading of the classroom noise level without the SNR device. On the second visit, the researcher would install the SNR device and take the reading of classroom noise level. This sequence was repeated many times during a period of 12 months across the three mathematics classrooms. In analysing data, the researcher studied different lessons and only compared the classroom noise level of those classrooms where the learners were involved in similar activities.

The mean of classroom noise level without the SNR device was calculated and compared with the mean of classroom noise level with the SNR device. Two sets of data are presented as line graphs on the same for comparison purpose (see, Figure 5.6, Figure 5.7 & Figure 5.8). In the main study, the data related to the classroom noise level with the SNR device and without the SNR device were captured on the same lesson. In the first part of the lesson, the SNR device would be installed in the classroom, and about halfway during the lesson, the SNR device would be switched off. In the main study, data related to classroom noise level were measured using a SLM with the noise level software. The instant noise level in dBA was captured in every two seconds. The computerised noise level software calculated the mean noise level and instantly changed into a line graph (see Figure 5.17, Figure 5.18 & Figure 5.19).

4.7.5 Error analysis of learners' mathematics achievement tests

Data related to learners' errors in different mathematics achievement tests were analysed using descriptive statistics with the mean, frequencies and simple percentages. Learners wrote mathematics achievement tests in the classroom with different noise environments.

The tests were administered to the learners in the classroom with the noise level environment ranging from 70 to 80 dBA. Thereafter, the classroom noise level was regulated in the range of 50 to 60 dBA, using the SNR devices. In marking learners' mathematics tests, the researcher used nominal numbers in coding the types errors made by Grade 10 learners.

Table 4.8 shows the nominal numbers used to code learners' errors in mathematics tests.

Table 4:8 Mathematics test: Rubric codes guidelines

Description	Correct answer /Step	Incorrect answer /Step	No answer /Attempt
Code	1	2	3

In marking, the correct answer or step was marked with a digit 1. The incorrect answer or step was marked with a digit 2, and no attempt or no answer was marked with a digit 3. Responses of similar codes, written in the same noise level environment, were tallied together per learner in different topics, (in this section, the word topic is referring to the algebra, Euclidean geometry and basic mental calculations tests). To obtain the total class mathematics errors per code, for each topic in the same noise level environment, all individual learners' tallied responses were combined together. The total class mathematics errors per code, per topic in the same noise level environment of each school are presented in the compound bar graph (see the figures in Section 5.3.4 & Section 5.4.3).

The advantage of the compound bar graph per mathematics topic is that it makes it easier to compare learners' mathematics errors in each code per school in two different noise environments. The researcher further combined the analysis all schools per each mathematics topics schools in two different noise environments; meaning that 18 compound bar graphs were combined and make three compound bar graphs. This allowed the researcher to narrow the interpretation of learners' errors in terms of each of mathematics topic (see, Section 5.4.3.5). The researcher finally combined the three compound bar graphs into one. This means that data from all six schools (regardless of

the mathematics topic) could be analysed according to the three codes (1. correct answers, 2. incorrect answers or 3. no answer) (see, Figure 5.36). This step-by-step and meticulous analysis of learners' errors in different tests in mathematics and the learners' after-survey were designed to answer the main research question and sub-research question 2, 4, 5 and 6. Most importantly, the data generated by means of learners' errors analysis in different tests in mathematics was used to test the hypotheses of the study.

4.8 INFERENTIAL STATISTICS

Slavin (2007) defines inferential statistics as the analysis which is used to compare groups to each other. In this study, the analysis of variance (ANOVA) was used to test the relationship between the number of errors that the learner participants made in three different mathematics achievement tests that were written in two contrasting learning environments across six schools. The analysis of the tests was conducted in a way that revealed learners' correct answers, incorrect answers and instances were test respondents did not provide answers. These mathematics achievement tests were written when the SNR device was used in the classroom with the noise level range of 50 to 60 dBA. Thereafter, they were written when the SNR device was not used in the classroom with the noise level ranging from 70 to 80 dBA.

4.8.1 The study hypotheses that were tested using the ANOVA

Data related to the analysis of learners' errors in different mathematics achievement tests were used to test the hypotheses of the study using two-way ANOVA.

4.8.1.1 Hypothesis 1

The first assumption was: *The use of the SNR device during a mathematics lesson increases learners' accurate answers in mathematics.*

To test this assumption a two-way ANOVA was used to test the accuracy of learners' responses that were made in the algebra, Euclidean geometry and basic mental calculations tests when the SNR device was used and when it was not used.

4.8.1.2 Hypothesis 2

The second assumption was: *The use of the SNR device during a mathematics lesson reduces learners' ECL in mathematics.*

To test this assumption, a two-way ANOVA was used to test the number of incorrect answers that the learners made in the algebra, Euclidean geometry and basic mental calculations tests when the SNR device was used and when it was not used.

4.8.1.3 Hypothesis 3

The third assumption was: *The use of the SNR device during a mathematics lesson increases learners' motivation to engage on the task.*

To test this assumption, a two-way ANOVA was used to test the number of times that learners failed to attempt a question and left it blank in the algebra, Euclidean geometry and basic mental calculations tests when the SNR device was used and when it was not used.

4.8.1.4 The main hypothesis of the study

The main assumption was: *The use of the SNR device during a mathematics lesson enhances learners' performance in mathematics.*

To test this assumption, a two-way ANOVA was used to test all three codes (number of correct answers, number of incorrect answers, number of no answer), across three topics used in mathematics achievement tests (the algebra, Euclidean geometry and basic mental calculations tests) across all schools. A two-way ANOVA test was performed when the SNR device was used and when it was not used.

4.9 ETHICAL CONSIDERATIONS OF THE STUDY

Ethical considerations were closely adhered to for the duration of the study. Holly, Arhar and Kasten (2005) recommend some of the ways in which researchers in

education adhere to these ethical requirements. The following ethics related steps and activities were considered for the study:

- Written permissions to participate in the study were received from learners, parents, school management, and the education department. These forms of permissions entailed learners' assenting forms and consenting forms from adults.
- A parent or a guardian prior to each learner's participation in the study signed consent forms.
- Anonymity for participants' identities was ensured.
- All study participants were informed of their right to withdraw, hence all forms of participation in the study were voluntary.
- The researcher ensured that a relationship of trust between researcher and participants was built ahead of the commencement of the research activities of the study.
- The researcher was self-reflective and avoided to influence the respondents' judgement.
- Confidentiality was also ensured.

4.10 SUMMARY OF THE CHAPTER

This chapter presented the methodology that was used to collect and analyse data to answer the main research question (Section 1.8.1). The study followed the intervention research design and used the mixed methods research design to collect and analyse the data (see, Section 4.2 & Section 4.3). The population and the sample of the study were discussed in Section 4.3.1. This chapter presented a discussion of the data collection instruments and their purposes. The following data collection instruments were discussed: teachers' questionnaires (Section 4.4.1), SLM (Section 4.4.3), lesson observation instruction guidelines (Section 4.4.4) mathematics achievement tests (Section 4.4.6) and the learners' post-test questionnaire (Section 4.4.7). The chapter discussed the three phases of data collection, namely, the preliminary phase (Section 4.3.4.10), the pilot phase (Section 4.5.2) and the phase that consisted of the collection of data in the main study (Section 4.5.3). In addition, the chapter provided a comprehensive discussion of

data analysis processes for the study (Section 4.7). The ethical issues were also discussed in Section 4.9. The next chapter presents the research findings of the study

CHAPTER FIVE
RESEARCH FINDINGS

5.1. INTRODUCTION

This chapter presents data findings that were collected during the three phases of the study. Data collected in School A at the preliminary stage were used to gather information to assemble the SNR device. Data collected for the pilot study in Schools A, B and C were presented in terms of:

- teachers' responses from the questionnaire that intended to reveal their perceptions, experiences and attitude towards the noise inside their mathematics classroom, also the surrounding noise from outside the classroom and school premises;
- the data that were intended to validate the SNR device;
- the data related to the level of classroom noise in a classroom environment without the SNR device and thereafter with the SNR device in Schools A, B and C; and
- the comparison of learners' mathematics errors that were committed in a classroom environment with the SNR device and errors made in a teaching environment that was without the SNR device.

The data collected in a main study in schools D, E and F are presented in the following order:

- teachers' responses from the questionnaire that were intended to reveal teachers' perceptions, experiences and attitude towards the noise inside the mathematics classroom, also the surrounding noise from outside the classroom and school premises;
- the data relating to the level of classroom noise in a classroom environment without the SNR device and thereafter with the SNR device in schools D, E and F.
- the data related to learners' mathematics errors committed in a classroom environment controlled by the SNR device compared to the errors made without the SNR device in the mathematics classrooms.

- the data of learners' responses relating to their experience as they responded to the post-test learners test in a classroom environment of 70 to 80 dBA.

5.2. PRELIMINARY PHASE DATA ANALYSIS

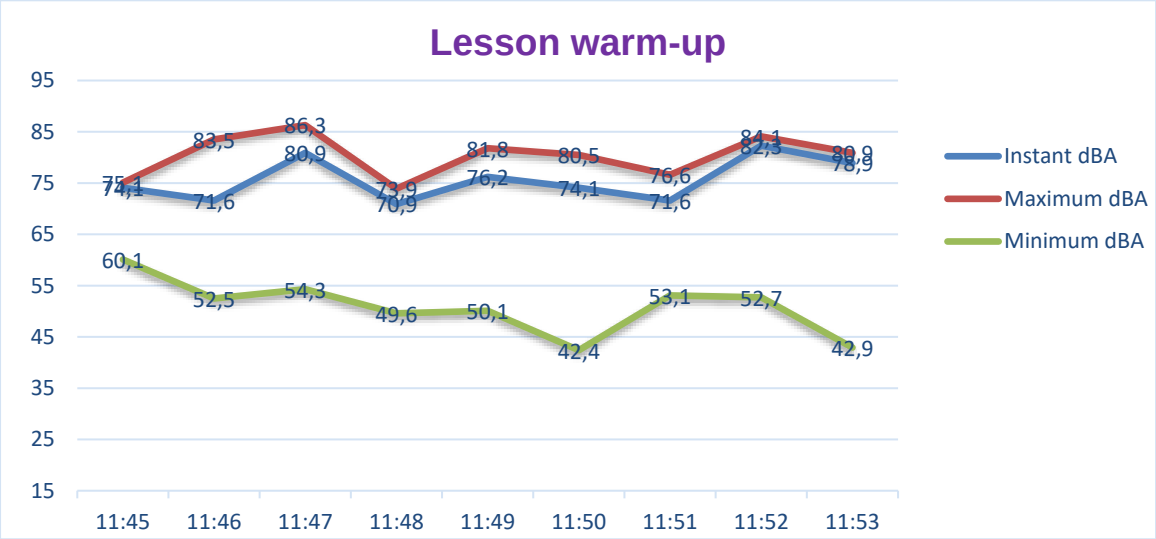
At the beginning of this study, data related to the noise level and the sequence of phases of mathematics lesson was collected in School A as a preliminary study for a period of one year. The preliminary phase of data collection in School A focused on gathering all the needed information to assemble the SNR device. The data were used to develop the prototype of the SNR device (see, Section 3.2). The data for the noise level in the classrooms collected in the first phase were programmed in the SNR device.

During the process of collecting data related to the noise level in mathematics classrooms, the researcher followed the flow of the lesson and took note of the types of activity that the class was involved in. This was done regardless of whether it was the introduction of a new topic, the teacher alone is explaining the new concepts or procedures independently, group classwork or individual assessment. The duration of each section of the mathematics lesson was noted and included into the SNR device's inbuilt features (see, Section 3.2). The following sections present the data findings that were used to determine the acceptable noise level as learners entered the classroom, followed and responded to the teacher instructions and as learners engaged in group work and individual work. The data were thereafter programmed into the SNR device prototype.

5.2.1. First phase of the lesson: Warm up and review

As learners entered the classroom, the noise level seemed to increase. Learners' movements when finding their seats, the movement of chairs and tables and the learners' concluding discussions that they walked to the classroom caused this increase of the noise level. The next graph shows a sample data of the instantaneous learners' noise level as they entered the classroom. The noise level was ranging from 71dBA to 82dBA.

Figure 5.1: Noise level in dBA during the first phase of a mathematics lesson



The researcher adopted a range of 70 to 80 dBA as the acceptable noise range, as learners entered the classroom. The range of 70 to 80 dBA was based on different noise level data that was collected at different times of the day and year. The researcher also noticed that the movement of learners as they entered the classroom lasted between two to five minutes.

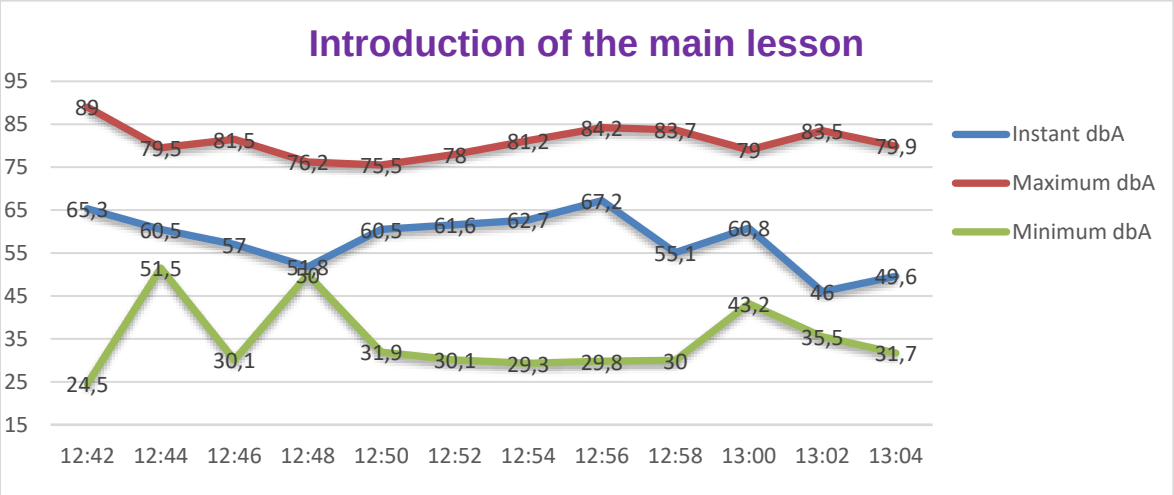
5.2.2. Second phase of the lesson: Introduction of the new concept

As learners settled in the classroom, the teacher would introduce the outline of what was going to be learned on that particular period. The researcher observed that most of the time learners were eager to listen to what the teacher had to say. At this phase, one person would be allowed to speak at a time. Some of the activities that the researcher observed were that a teacher would do one or two sums of the previous homework on the board, or sometime the teacher would ask a learner to do the sum while other learners were watching in silence. In other instances, the teacher introduced a new topic. It was in a rare situation that learners' noise level exceeded 80 dBA. For instance, when a teacher asked the question such as, "*Did you understand the homework*?", all learners would

respond at the same time saying, “*no*” or “*yes*”, and sometimes with mixed responses of “*yes*” and “*no*”.

The following graph presents a sample of data for the instantaneous learners’ noise level as the teacher started the lesson. The noise level was ranging from 46dBA to 66dBA, with an instant average of 58dBA.

Figure 5.2: Noise level in dBA during the second phase of a mathematics lesson



Average instant dBA for 40 minutes period: 58 dBA
Average maximum dBA for 40 minutes period: 81 dBA
Average minimum dBA for 40 minutes period: 35 dBA

As the teacher started the lesson, the researcher adopted a range of 60 to 70 dBA as the acceptable noise range. The range of 60 to 70 dBA was based on several noise level data that were collected at different times of the day and year. The researcher also noticed that the activities in this phase could exceed 10 minutes if it were not monitored. For instance, the activities could go beyond 10 minutes. In the SNR device, this phase was set for nine minutes.

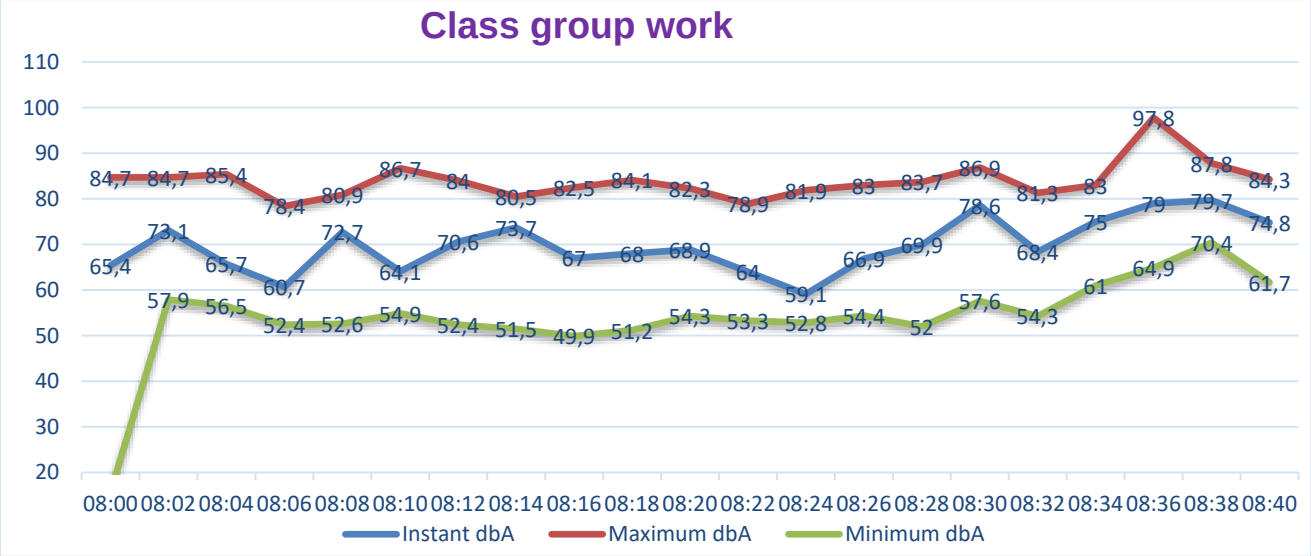
5.2.3. Third phase of the lesson: Work examples, practice and explore

During the observation, the researcher noticed that the classroom noise increased when learners were working in groups in order to explore different methods for problem solving. The following graph shows a sample data of the instantaneous learners’ noise level where

they were working in groups. The noise level was ranging from 59 to 80dBA, with an instant average of 70dBA.

Given the great emphasis that several experts in mathematics education place on learners' group work and exploration, the researcher attributed 13 minutes to this phase. The researcher also allowed the noise level in this phase to be in the range of 70 to 80 dBA.

Figure 5.3: Noise level in dBA during the third phase of a mathematics lesson



Average instant dBA for 40 minutes period: 70 dBA
Average maximum dBA for 40 minutes period: 84 dBA
Average minimum dBA for 40 minutes period: 54 dBA

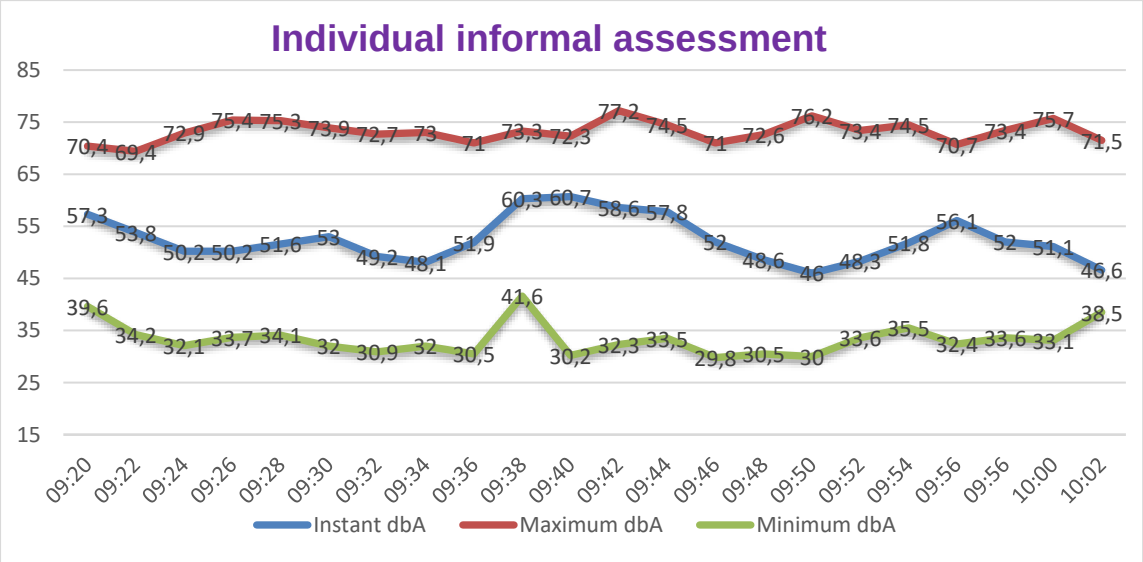
5.2.4. Assessment and consolidation test

The researcher observed that apart from the schedule formal test, learners were rarely given time to work out mathematics sums on their own in a silent classroom environment. Frequent assessments in a quiet classroom environment may be one of the solutions to alleviate assessment anxieties (Spangenberg, 2018). Some learners commented that the unusual silent environment in the examination hall raised their anxieties and sometimes would make them to break out, stating that the environment is awkward because it is not similar to the learning environment that they are familiar with (Smith, 2004). Finding a

silent environment conducive to learning outside the classroom may be a challenge in a metropolitan city. It is common in Johannesburg's metropolitan life for a family with children to live together in one room. This means that the learners' home living conditions would not provide a silent environment to reflect on mathematics concepts that they have learned at school.

During the pilot study, the researcher was able to observe sessions whereby learners were silently writing a class test. This provided the researcher with an opportunity to record data about learners working on their own in a silent environment. The following graph presents a sample data of learners' instantaneous noise level when they were working individually doing an assessment or performing a consolidation test. The noise level ranged from 47-61dBA, with an instant average of 53dBA.

Figure 5.4: Noise level in dBA during the fourth phase of a mathematics lesson

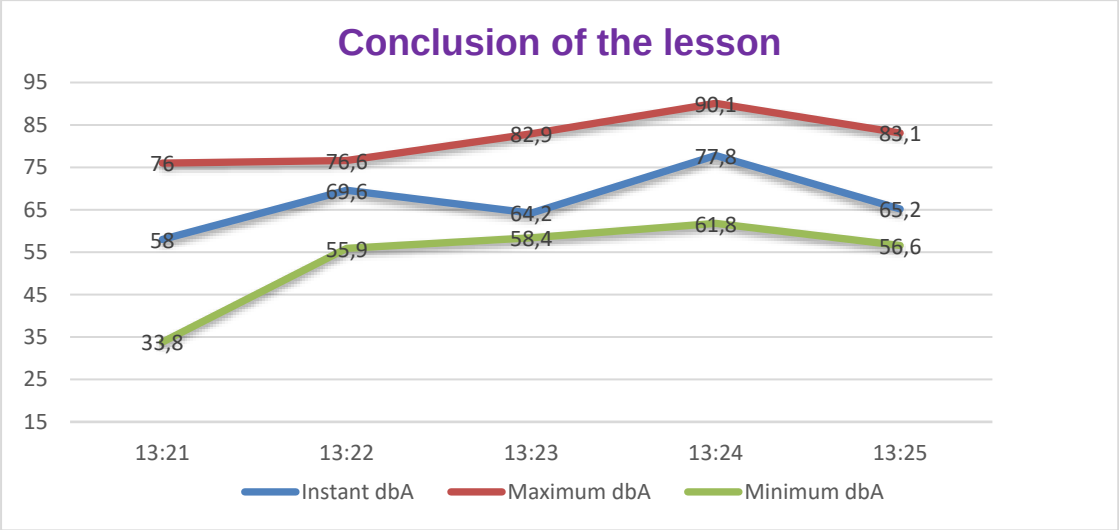


Based on the reasons in the preceding section, the researcher allocated ten minutes to this phase in the SNR device. The ten minutes classroom assessment was used to consolidate what was learned to allow learners to assimilate what they had learned from a teacher, classmate (one on one), or in a group in an environment like the formal testing environment. The researcher set the noise level in this phase to be in the range of 50 to 60 dBA for ten minutes.

5.2.5. Administration and closure

At the conclusion of the lesson, the noise level in the classroom seemed to increase. This was caused by several activities that took place such as learners walking to the teacher to mark their books. In some cases, the teacher marked the register at this time if it was not taken at the introduction of the lesson. In addition, the teachers informed the learners of the page where they would find the homework in their textbook. The researcher observed and recorded the noise level as the teachers were concluding the mathematics lesson. The following graph presents a sample data of learners' instantaneous noise level when the teacher was concluding the lesson and walking out of the classroom.

Figure 5.5: Noise level in dBA during the fifth phase of a mathematics lesson



Average instant dBA for a five minutes period: 67 dBA
Average maximum dBA for a five minutes period: 82 dBA
Average minimum dBA for a five minutes period: 53 dBA

The noise level ranged from 57 to 78 with an average 67dBA. The researcher set the noise level in this phase to be in the range of 70 to 80 dBA for three minutes.

5.3. PILOT DATA FINDINGS

The data collected for the pilot study in Schools A, B and C is presented in the following order,

- data intended to validate the SNR device;
- teachers' responses from the questionnaire that intended to reveal their perceptions, experiences and attitudes toward noise inside the mathematics classroom, and the surrounding noise from outside the classroom and school premises;
- data related to the level of classroom noise in a classroom environment without the SNR device and thereafter with the SNR device in Schools A, B and C; and
- data comparing learners' mathematics errors in a classroom environment with the SNR device and errors made without the SNR device in the classrooms.

5.3.1. Validation of the SNR device

During the pilot phase of the study, the SNR device was rolled out in the research field in School A, B and C. The main purpose of piloting the SNR device was to test the effectiveness of the SNR device in regulating and even reducing learners' noise level in mathematics classrooms. In line with the A-B-A-B design, the researcher would on the first day take the reading of classroom noise level without the SNR device. On the second day, the researcher would install the SNR device and take the reading of the classroom noise level. This sequence was repeated many times during a period of 12 months across the three mathematics classrooms. The 12 months allowed the researcher to use the device for different topics of mathematics and at the different times of the day. The findings of the pilot study revealed factors that influenced learners' noise in the mathematics classroom. In addition, the findings revealed the types of noise that may be controlled by the SNR device and those that cannot be controlled. Several adjustments were made in the SNR device noise level, also in the methods of collecting data to answer the research questions (Section 3.2 & Section 4.5.2.4). The key findings of the pilot data collection are discussed next, and thereafter the encountered limitations.

Table 5.1: The SNR device validation checklists

Questions that guided the validation	Yes	No	Comments
Do all mechanical components of the SNR device work effectively?	YES		No malfunctioning or technical breakdown experienced.
Does the SNR device respond to the accurate noise level?	YES		
Does the timing of the lesson feature in the SNR device working in the way it was programmed?	YES		
Does the SNR device respond to the classroom noise level instantly?		NO	
Does the SNR device differentiate the noise of the teacher, learners or school bell?		NO	
Does the SNR device pick up and respond to soft sounds and whispers?		NO	
Does the SNR device pick up and respond to the noise coming from outside the classroom?	YES		
Does the SNR device pick up and respond to the noise coming from outside the school premises?	YES		
Do learners see and respond to the traffic light signals of the SNR device?	YES		
Does the SNR device distract learners at a certain level?	YES		
Are learners interested to have the SNR device in their classrooms?	YES		
Is the sequence and the timing in the SNR device follow teachers' sequence of the lesson?		NO	
Are teachers interested to have the SNR device in their classrooms?	YES		
Can the device be moved at any different location in the classroom?	YES		

5.3.2. Pilot study teacher questionnaire responses

A questionnaire was designed to elicit responses from Grade 10 mathematics teachers. Teachers' responses provided an overall understanding of their perceptions and attitudes toward noise level both inside and outside mathematics classrooms.

The teachers were asked to rate their responses on the Likert scale from 1-7 to indicate the extent to which they have experienced noise in their teaching of a Grade 10 mathematics class (Appendix D).

Table 5.2 shows teachers' responses in schools A, B and C.

Table 5.2: Pilot study teacher questionnaire responses

	Max. code	7	6	5	4	3	2	1	Mean range
		Always	Very frequently	Frequently	Occasionally	Rarely	Very rarely	Never	
	Likert scale range	$6 < r \leq 7$	$5 < r \leq 6$	$4 < r \leq 5$	$3 < r \leq 4$	$2 < r \leq 3$	$1 < r \leq 2$	$0 < r \leq 1$	
Experiences learners' noise					B		A C		2,7
Learners' noise turns out to be disruptive behaviour.					B	C	A		3
Learners' noise turns out to affect fellow learners' concentration.					B	C	A		3
Losing teaching time because of learners' noise					B	A	C		3
Failing to achieve the lesson objective because of learners' noise							A	B C	1,3
Feeling irritated because of learners' noise					A B		C		3,3
The noise coming from outside the school premises is affecting the lesson							B C	A	1,7
The noise coming from inside the school premises is affecting the lesson				C	A		B		3,7
Ignoring the learners' noise and carrying on with the lesson							C	A B	1,3
Learners complaining that they cannot hear the teacher because of the noise level.							A	B C	1,3

The mean responses of the teachers' questionnaire show the extent to which teachers were affected by noise in their practice. They mentioned that they occasionally felt irritated because of learners' noise during a mathematics lesson. They also mentioned that the noise coming from inside the school premises occasionally affected their lesson delivery. Teachers mentioned that on rare occasions, learners' noise would constitute a disruptive behaviour or affect fellow learners' concentration. In addition, it was revealed that on rare occasions teachers would lose some of their teaching time because of learners' noise.

On very rare occasions, teachers would ignore learners' noise and carry on with the lesson. At the same time, on very rare occasions would teachers fail to achieve the lesson

objective because of learners' noise. It was rare that learners complained that they could not hear the teacher because of the noise level of noise. Regardless of whether the school was located in suburbs, near the railway line or in old building structures, the teachers in Schools A, B and C mentioned that the noise from outside the school premises affected their lesson on rare occasions.

5.3.3. Data related to the level of classroom noise level in the pilot study

Data related to the trend of learners' noise level in each mathematics classroom in the pilot phase were measured using a SLM. The researcher recorded the instant noise level in dBA every two minutes. Each school was visited once a week. Every week the SNR device was alternatively installed in the classroom; meaning that if the first week the sound level was taken without the SNR device, the following week the sound level would be taken with the SNR device installed in the classroom. The tests were administered to the learners in the classroom with the noise environment ranging from 70 to 80 dBA. To maintain this level of noise in the classroom, local and popular songs were played amplified from 70 to 80 dBA and monitored by the SLM. The rational of playing the music instead of creating other kind of noise in the classroom, was to comply with research ethics (Section 4.9). In addition, the type of music played was helpful in eliminating extraneous variables that could have affected the internal validity of the study such as tiredness and stress (Section 4.6.3.3). Whenever the classroom noise level needed to be regulated, the SNR device was used, and the sound meter monitored that the noise was ranging from 50 to 60 dBA.

As stated by Kennedy-Clark (2013), intervention research design may generate more data. This study collected a lot of data. During the first months of data collection, data seemed to be overwhelming and vague for interpretation. The reason was that each lesson is unique, therefore the classroom noise level also differed accordingly. To overcome this limitation, the researcher only compared noise level of the classrooms that took place on the same time of the day. The researcher decided to only compare the noise level of the classrooms that took place on the same time of the day to eliminate others factors that may be influencing learners' noise variation during the lesson. For instance, the researcher observed that in the morning, learners seemed to keep their noise level

under control, but after the break or lunch time, learners seemed to increase their noise level. These findings corroborate those of Pope (2016) who found that in the morning, learners in Grade 9 to 11 are more productive and engaged in their classroom than in afternoon. Therefore, comparing noise level of the classrooms that took place on the same time of the day meant that the researcher was comparing classes with same motivation to learn. In addition, the researcher studied different lessons and only compared the classroom noise level in which learners were involved in similar activities. In the next section the noise level in Schools A, B and C is presented. Data were taken by the sound level meter and recorded on the noise recording sheet (see, Sections 4.4.3 & 4.4.4) and the data were used to generate the graph.

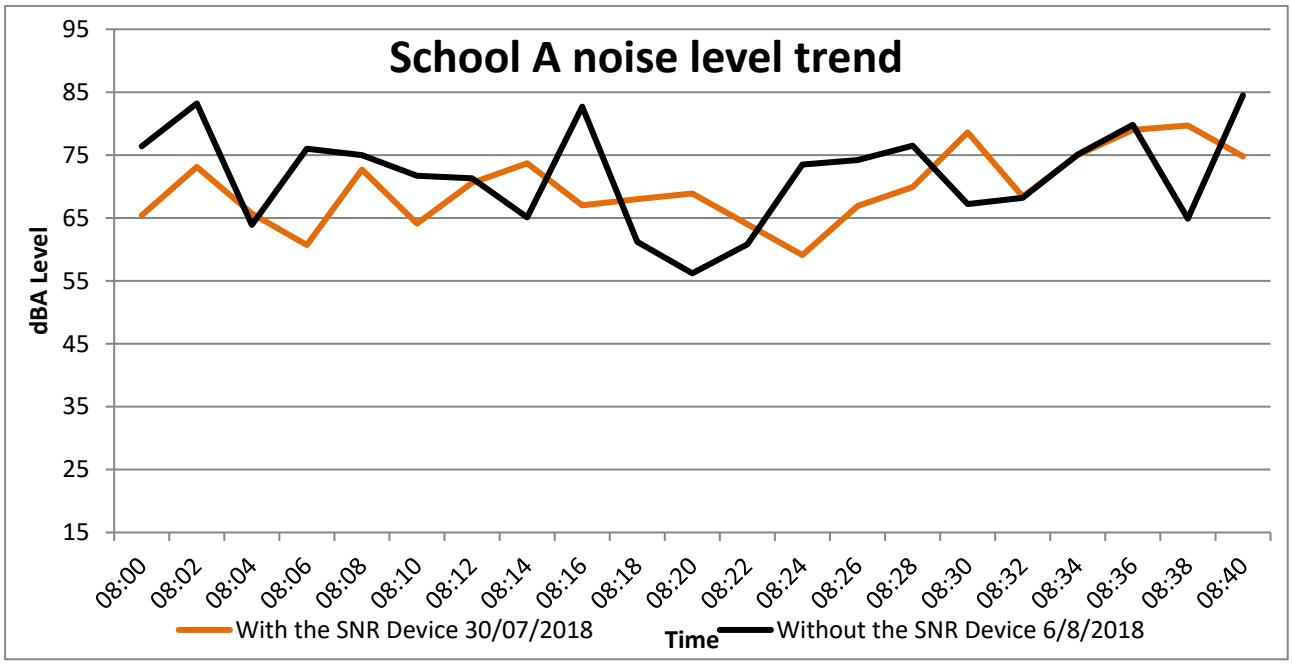
5.3.3.1. Noise level in School A

School A was located in the suburb of Johannesburg and the mathematics class in this school had 32 learners. The noise level data, with the SNR device installed in the classroom, was taken while the class had a discussion. The lesson was based on Euclidean geometry, learning the properties of a parallelogram. The teacher explained the key concepts and used probing questions to engage learners in the discussion (see, Section 5.2.2). What raised the noise level was that the majority of learners shouted out their answers. About three times the noise level was in the range of 75 to 80 dBA and triggered the red light of the SNR device. The noise level data without the SNR device in the classroom was also taken when the class had a discussion (see, Section 5.2.3).

The class was involved in Euclidean geometry activities learning the mid-point theorem using a triangle. Similar to a preceding lesson in a week, the teacher explained the key concepts and used probing questions to engage learners in the discussion. In a class of 30 learners, only ten learners seemed to be fully engaged. There were at least eight learners disturbing others at any time of the lesson. At some point, one learner was singing while another learner was throwing an eraser to a fellow learner. The general observation was that the majority of learners seemed to be daydreaming, meaning that the learners were preoccupied in thinking or involved in matters not related to learning mathematics. For more than five times, the noise level was in the range of 75 to 80 dBA and triggered

the red light of the SNR device. The next graph presents the noise level trend in School A.

Figure 5.6: Noise level (dBA) trend in School A



The average with the SNR device was 69,8 dBA while the average without the SNR device was 71,8 dBA. The classroom without the SNR device seemed to experience an increase of 3% of the noise level. This substantial improvement was owing to the orderliness of the lesson.

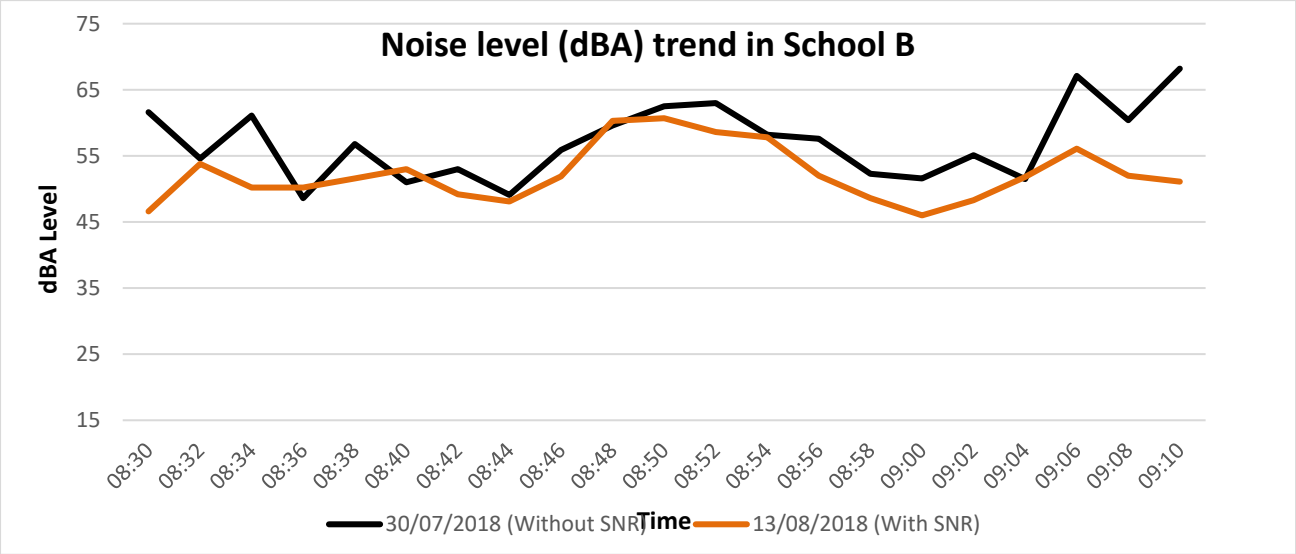
5.3.3.2. Noise level in School B

School B was located in an older building infrastructure around the City of Johannesburg metropolitan area with a mathematics class that had 29 learners. The noise level data without the SNR device in the classroom were taken while the class was busy with individual classwork on the analytical geometry. The teacher directed the learners to a specific page in their textbook and asked them to do a certain number of questions on their own. The teacher would walk around in the class and mark learners' individual work

as a form of feedback. Whenever the teacher noticed that learners were making the same mistake, the teacher would tell everyone to stop. The teacher would ask one learner to read out the question and the teacher would provide a brief (less than one minute) explanation, thereafter learners would continue their work. However, two learners were not engaged. These learners would simply be lying with their heads on the desks. When a learner was reading out the question, everyone would be quiet and listening, and the noise level would give a range of 54 to57dBA. The school bell recorded a 65dBA.

The noise level data with the SNR device installed in the classroom were taken on the same day after two weeks when the class was busy with the classwork as revision from previous question papers. The teacher would direct learners to a specific number on the question paper to do on their own. The teacher would walk around in the class and mark learners' individual work as a form of feedback. Whenever the teacher noticed that learners were making the same mistake, the teacher would tell everyone to stop. The teacher would ask one learner to read out the question and the teacher would provide a brief (less than one minute) explanation. Thereafter learners would continue with their work. During the individual work session, learners seemed to have been engaged. Some learners would seek help from fellow learners by whispering, also fixing their eyes on the SNR device so that they did not trigger a change of the SNR colour. The next graph presents the noise level trend in School B.

Figure 5.7: Noise level (dBA) trend in School B



The average with the SNR device was 52 dBA while the average without the SNR device was 57 dBA. The classroom without the SNR device experienced an increase of about 10% of the noise level.

5.3.3.3. Noise level in School C

School C is located in the near the railway line around the Johannesburg metropolitan. The mathematics class in this school had 38 learners. In the pilot study, the researcher captured the noise level in School C for 40 minutes, which was an official time allocated to the lesson. First, the noise level was recorded with the SNR device installed in the classroom and after two weeks, the noise level was recorded without the SNR device. The lessons recorded followed the same learning sequences of activities, as they happened at same time and day of the week, and these may be outlined as follows:

11:10 – 11:20: The teacher was explaining and doing the corrections of the previous work, which had been given to the learners as homework;
11:20 – 11:35: The teacher was giving learners individual work to do. While learners were busy the teacher would move around and explaining to individuals who seemed to be struggling with the work;

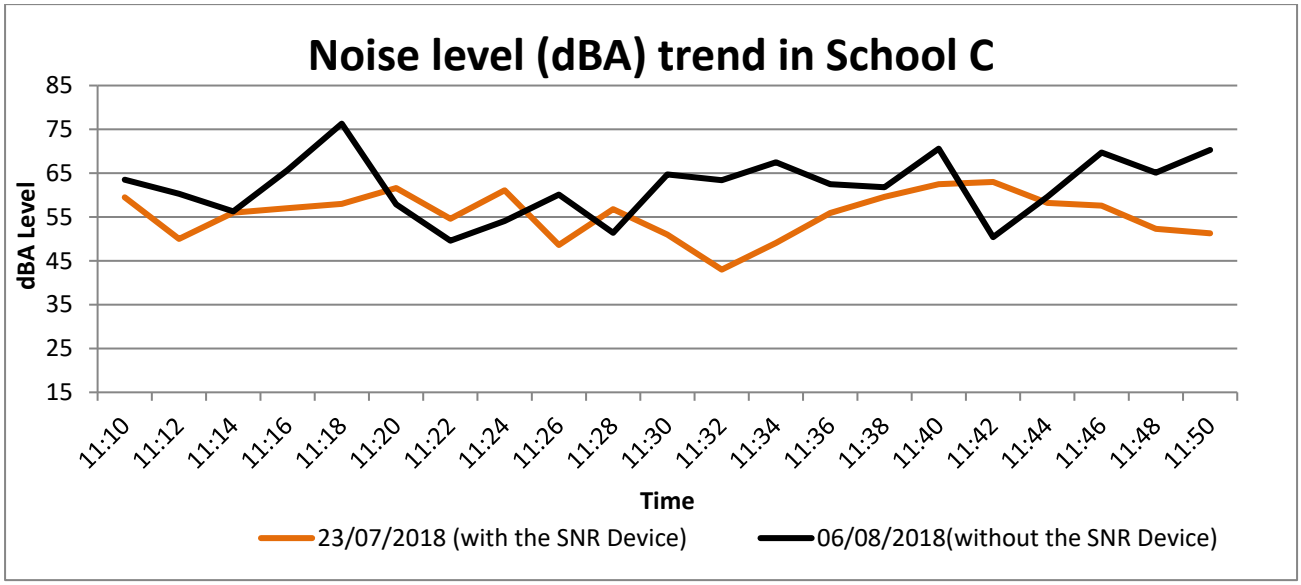
11:38 – 11:45: One learner would volunteer to go and do the corrections on the board while others were following along; and

11:45 – 11:50: The teacher was explaining more concepts and concluding the lesson.

In a class where the SNR device had not been incorporated the lesson was about compound interest. For the first ten minutes, at least 12 learners seemed to be off-task as they had private talks to one another in a low voice. About eight learners seemed to be daydreaming during teachers' explanations, meaning that the learners were preoccupied in thinking or involved in matters not related to learning mathematics. During the individual work, learners seemed to be all on-task and the noise was low. One learner fully was engaged in the work while simultaneously chewing a gum. When the teacher told the whole class to stop and requested them that they work together, many learners also sat around with a sense of relief and said, "*Yes let us do it together*", and this arrangement seemed to raise the noise level.

In a class where the SNR device was incorporated, the lesson was about analytical geometry. In this class, almost five learners were observed to be whispering to one another during the teacher's explanations. At the same time, they seemed to be occasionally engaged with the teacher. When the teacher asked a learner to read out the question so that another learner could go and put it on the board, everyone was quiet and listening, and the noise level during the reading was in the range of 54 to 57dBA. At one point while a learner was working out the question with a distance formula on the board, the learner forgot to put the square root and the majority of the class kept on saying, "put the square root". The SNR device showed a red colour and learners responded in isi-Zulu (Senzeni?), meaning, "*What wrong have we done"*? The school bell recorded 70dBA and the movement of learners outside the classroom during the changes of period was 63 dBA. The next graph presents the noise level trend in School C.

Figure 5.8: Noise level (dBA) trend in School C



The average noise level with the SNR device was 55.6 dBA while the average noise level without the SNR device was 61.9 dBA. The classroom without the SNR device experienced an increase of 11% of the noise level.

5.3.4. Data related to learners' mathematics errors

Learners wrote three types of mathematics achievement tests in a classroom environment with a high level of noise, and thereafter in a normal environment with a noise level conducive to learning. The algebra questions were intended to test the dissimilarities of learners' cognitive and thinking abilities when they were involved in learning mathematics topics with abstract content. The geometry questions were intended to test learners' performance when involved in learning mathematics topics with concreate content. Mental mathematics calculations were intended to test learners' listening skills and the ability to process and recall information in a short period of time in two different noise learning environments.

The tests were administered to the learners in the classroom with the noise environment ranging from 70 to 80 dBA. To maintain this level of noise in the classroom, local and popular songs were played, amplified from 70 to 80 dBA and monitored by the SLM.

Whenever the classroom noise level needed to be regulated, the SNR device was used and the sound meter monitored that the noise was ranging from 50 to 60 dBA.

During the pilot study in Schools A, B and C learners first wrote the test in the noisy environment, and thereafter the SNR device controlled the noise (see, Table 5.1). The SLM was used to monitor that the noise ranges from 50 – 60 dBA.

The researcher noticed that the sequence of starting with music first and later controlling the noise created the carry over effects. For example, the carry over effect would occur when some learners were moving their heads and hands in the tune of the previous songs. In addition, it could have been argued that the maturation effects influenced the improvement of learners' performance in the test; meaning that from the pre-test learners could have been able to anticipate what would come in the post-test.

These observations motivated the researcher to change the sequence in which the tests would be administered to the learners in the main study. In the main study in Schools D, E and F learners first wrote the test in the environment controlled by the SNR device with the noise ranges from 50 to 60 dBA, and thereafter in a noisy environment with music amplified to 70 to 80 dBA (see, Table 5.1).

5.3.4.1. Errors in algebra in the pilot study

The researcher used the algebra test to determine how learners use their mental process when performing tasks with an abstract content, in two different noise learning environments. The tests were designed to uncover the extent to which learners' cognitive thinking would be affected by the noise level inside the classroom. The cognitive thinking requires that learners be able to comprehend, process, remember, and applying the information. The algebra test was designed to assess learners' comprehension of the question; to assess the extent to which they remembered the algebraic rules, processing the rules; and to apply the information to evaluate and solve the problem (see, Appendices A_1 & A_2).

The tests were administered to Grade 10 learners in a school located in the in three different settings (Section 4.3.1.3). When marking the learners' tests, the researcher

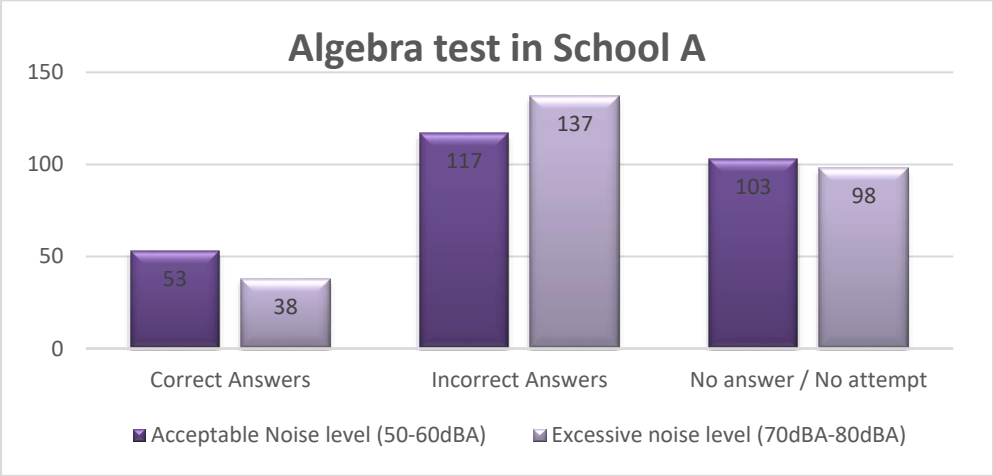
followed the marking guidelines (Appendix A_1 & A_2). Nominal numbers were used to represent types of errors. Any correct answer or any correct step leading to a correct answer was marked with a digit 1. Any attempt to answer the question or any incorrect step leading to an incorrect answer was marked with a digit 2. Any section of the question which is not answered was marked with a digit 3.

The following sections present the data related to errors made by learners in the algebra test in the pilot study in schools A, B and C.

5.3.4.1.1. Learners' errors in algebra test in School A

School A was located in one of the suburbs in Johannesburg. The tests were administered to Grade 10 learners (see, Section 4.3.1.3.1). The next graph represents the algebra test results in School A.

Figure 5.9: Noise level (dBA) trend in School A



In the uncontrolled noise classroom environment, learners scored 38 correct answers, and in a classroom environment with acceptable noise level, learners scored 53 correct answers. This accounts for an increase of 39% of learners' accuracy in algebra.

In the uncontrolled noise classroom environment, learners made 137 incorrect answers, and in a classroom environment with acceptable noise level, learners made 117 incorrect

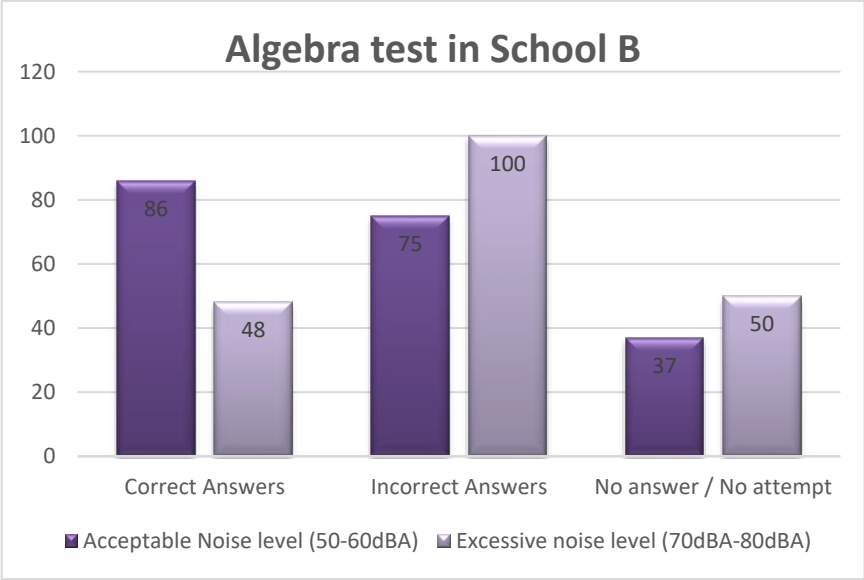
answers. This indicates that by controlling the noise, the incorrect answers decreased by 15%.

In the uncontrolled noise classroom environment, learners made no attempt to 98 answers, and in a classroom environment with acceptable noise level, learners made no attempt to 103 answers. This means that learners in an acceptable noise classroom environment exerted themselves to solve the algebra questions, spent more time in getting correct answers and did not attempt to answer five additional questions.

5.3.4.1.2. Learners' errors in the algebra test in School B

School B was one of the sampled schools located in an older building structure. The school was over 100-year-old in the Johannesburg metropolitan (see, Section 4.3.1.3.3). The next graph represents the algebra test results in School B.

Figure 5.10: Learners' errors in algebra in School B



In the uncontrolled noise classroom environment, learners scored 48 correct answers, and in a normal noise classroom environment, learners scored 86 correct answers. This accounts for an increase of 79% of learners' accuracy in algebra.

In the uncontrolled noise classroom environment, learners produced 100 incorrect answers, and in a normal-noise classroom environment, learners produced 75 incorrect

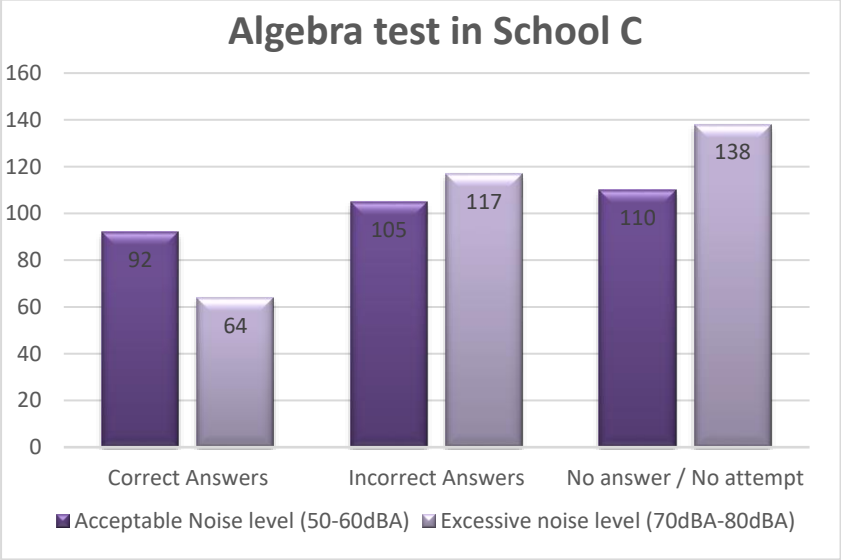
answers. This indicates that by controlling the noise, the incorrect answers decreased by 25%.

In the uncontrolled noise classroom environment, learners failed to attempt 50 questions, and in a normal noise classroom environment, learners did not attempt to answer 37 questions. This indicates that by controlling the noise, learners were encouraged to attempt to answer many questions by 26%.

5.3.4.1.3. Learners' errors in the algebra test in School C

School C was one of the sampled schools located near the railway line in the City of Johannesburg metropolitan area (see, Section 4.3.1.3.2). The next graph represents the algebra test results of School C.

Figure 5.11: Learners' errors in algebra in School C



In the uncontrolled noise classroom environment, learners scored 64 correct answers, and in a normal noise classroom environment, learners scored 92 correct answers. This accounts for an increase of 50% of learners' accuracy in algebra. In the uncontrolled noise classroom environment, learners made 144 incorrect answers, and in a classroom environment with acceptable noise level, learners made 105 incorrect answers. This indicates that by controlling the noise, it decreased the incorrect answers by 27%.

In the uncontrolled noise classroom environment, learners failed to attempt 110 questions, and in a classroom environment with acceptable noise level, learners did not attempt to answer 99 questions. This indicates that by controlling the noise, learners are encouraged to attempt many questions by 11%.

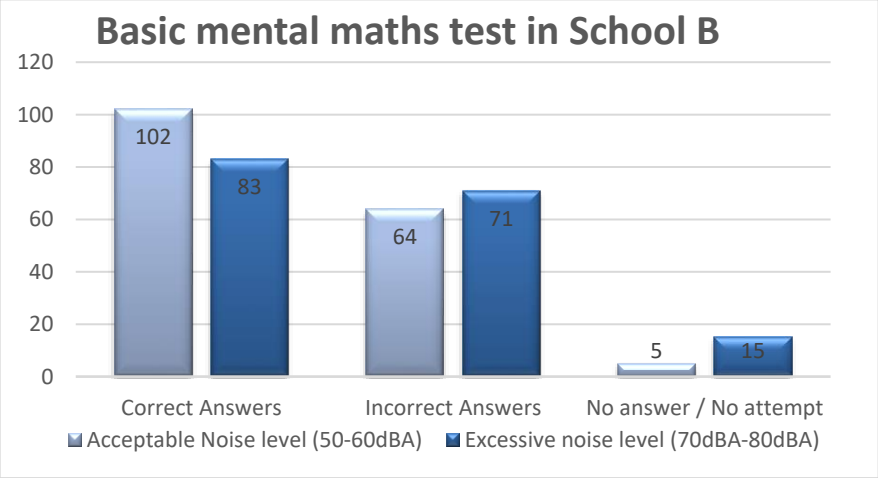
5.3.4.2. Errors in basic and mental calculations in pilot study

This study used simple and basic mental mathematics calculations for Grade 10 level. Questions 1 and 2 of the tests were designed to test learners' listening skills. The other remaining eight questions were intended to test learners' ability to process and recall information in a short period of time in two different noise learning environments. This was caused by the fact that by the time the mental calculations achievement test was to be administered, teachers at the school were not teaching. The teachers were on strike and the research permission by the GDE was about to expire the following week. This meant that the test could not be given to the same learners the following year as there would be another group of learners. Section 5.4.3.2.1 presents the data related to errors made by learners in the basic and mental tests in different schools. Thereafter, the responses of learners' post-test assessment are presented.

5.3.4.2.1. Learners' errors in the basic and mental mathematics test in School B

School B was one of the sampled schools located in the older building structure. The school was over 100-years-old and located in the City of Johannesburg metropolitan area (Section 4.3.1.3.3). The next graph represents the results in School B in the basic and mental mathematics test.

Figure 5.12: Learners' errors in the basic and mental mathematics test in School B



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 102 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 83 correct answers. This indicates that the increase of the noise in the classroom decreased the number of correct answers.

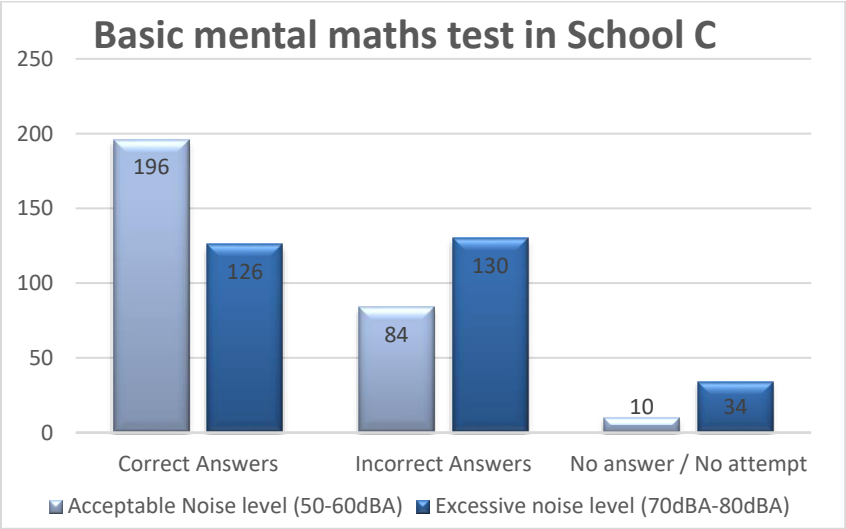
In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 64 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 71 incorrect answers. This indicates that the increases of the noise in the classroom also increased the incorrect answers by 11%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt five questions. In the classroom environment with a noise level of 70 to 80 dBA, learners fail to attempt to answer 15 questions. This indicates that by controlling the noise, learners were encouraged to attempt many questions by 200%.

5.3.4.2.2. Learners' errors in the basic and mental mathematics test in School C

School C was one of the sampled schools located near the railway line in the City of Johannesburg metropolitan area (Section 4.3.1.3.3). The next graph represents the results in School C in the basic and mental mathematics test.

Figure 5.13: Learners' errors in the basic and mental mathematics test in School C



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 196 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 126 correct answers. This indicates that the increase of the noise in the classroom decreased the number of correct answers by 36%.

In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 84 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 130 incorrect answers. This indicates that the increase of noise in the classroom also increased the number of incorrect answers by 55%.

In the classroom environment controlled by the SNR device with a noise level ranging from 50 to 60 dBA, learners failed to attempt ten questions. In the classroom environment with a noise level of 70 to 80 dBA, learners fail to attempt 34 questions. This indicates that by controlling the noise, learners are encouraged to attempt many questions by 71%.

5.3.4.3. Errors in Euclidean the geometry test in the pilot study

This study used the Euclidean geometry questions on topics that Grade 10 learners had already covered in the previous grades. The questions in the geometry test were designed to test learners' performance using their sense of vision as far as concrete learning was

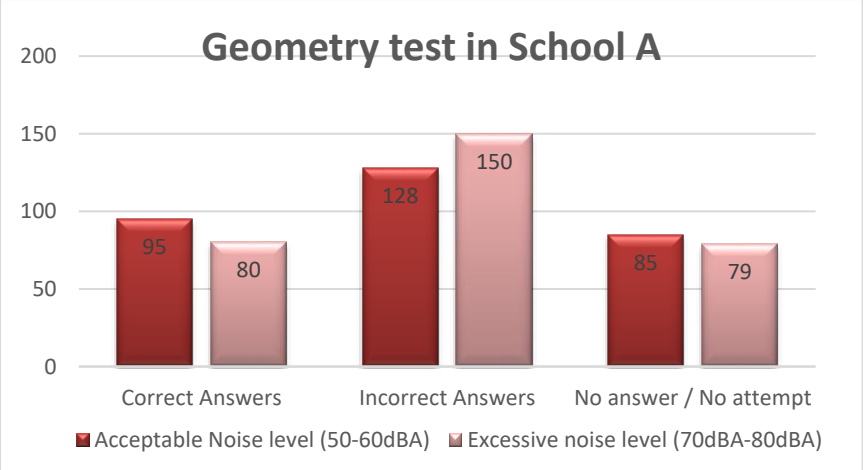
concerned. Learners needed to identify different angles in a triangle and parallel lines, formulate geometry statements with reasons and to find the size of angles. Errors made by learners during these Euclidean geometry tests were used to determine the extent to which the two contrasting noise learning environments affected learners' sense of vision and remembering the riddles.

Section 5.3.4.3.1 presents the data related to errors made by learners in the Euclidean geometry tests in different schools. Thereafter, learners' post-test responses are presented.

5.3.4.3.1. Learners' errors in Euclidean geometry test in School A

School A was located in the suburb of Johannesburg. The tests were administered to Grade 10 learners in a school located in the suburb of Johannesburg (Section 4.3.1.3.1) The next graph represents the results in School A in the Euclidean geometry test.

Figure 5.14: Learners' errors in Euclidean Geometry in School A



In the classroom environment controlled by the SNR device with a noise level ranging from 50 – 60 dBA, learners produced 95 correct answers. In the classroom environment with a noise level of 70 – 80 dBA, learners scored a total of 80 correct answers. This indicates that the increase of the noise in the classroom decreased the number of correct answers by 16%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 – 60 dBA, learners produced a total of 128 incorrect answers. In the classroom

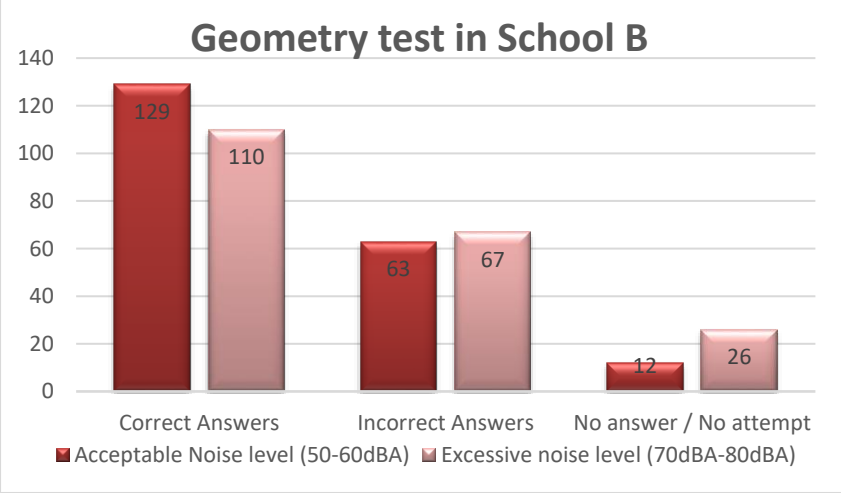
environment with a noise level of 70 – 80 dBA, learners produced a total 150 incorrect answers. This indicates that the increases of the noise in the classroom also increased the number of incorrect answers by 15%.

In a classroom environment controlled by the SNR device with the noise level ranging from 50 – 60 dBA, learners failed to attempt 85 questions. In the classroom environment with a noise level of 70 – 80 dBA, learners failed to attempt 79 questions. This shows a decrease of the number of attempts to answer the questions by 7%.

5.3.4.3.2. Learners' errors in Euclidean geometry test in School B

School B was one of the sampled schools located in the older building structure. The school was over 100-years-old and was located in the Johannesburg metropolitan (Section 4.3.1.3.3). The next graph represents the results in School B's Euclidean geometry test.

Figure 5.15: Learners' errors in the Euclidean geometry test in School B



In the classroom environment controlled by the SNR device with the noise level ranging from 50 – 60 dBA, learners produced 129 correct answers. In the classroom environment

with a noise level of 70 – 80 dBA, learners scored 110 correct answers. This indicates that the increase of the noise in the classroom decreased the number correct answers by 15%.

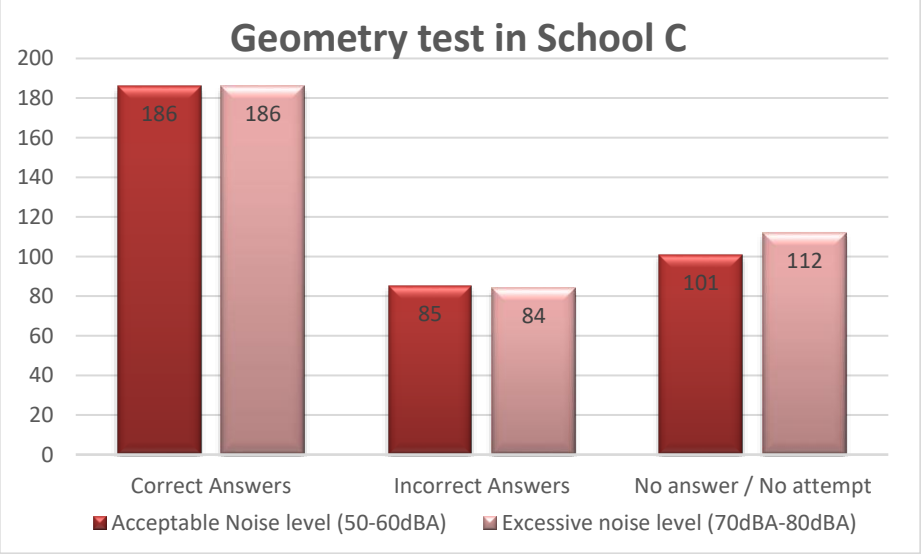
In a classroom environment controlled by the SNR device with the noise level ranging from 50 – 60 dBA, learners produced a total of 63 incorrect answers. In the classroom environment with a noise level of 70 – 80 dBA, learners produced 67 incorrect answers. This indicates that the increase of the noise in the classroom also increased the number of incorrect answers by 6%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 – 60 dBA, learners failed to attempt 12 questions. In the classroom environment with a noise level of 70 – 80 dBA, learners failed to attempt 26 questions. This indicates that by controlling the noise, learners were encouraged to attempt many questions by 54%.

5.3.4.3.3. Learners' errors in the Euclidean geometry test in School C

School C was one of the sampled schools located near the railway line in Johannesburg metropolitan (Section 4.3.1.3.3). The graph represents the results in School C in the Euclidean geometry test.

Figure 5.16: Learners' errors in the Euclidean geometry test in School C



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 186 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored a total of 186 correct answers. This indicates that learners' performance in this school in terms of the classroom environment was even.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 85 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced 84 incorrect answers. This indicates that the increase of noise in the classroom slightly decreased the incorrect answers by 1%.

In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt 101 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt 112 questions. This indicates that by controlling the noise, learners were slightly encouraged to attempt questions by 1%.

The overall performance of School C in the geometry test seems to be even.

5.4. THE MAIN STUDY DATA FINDINGS

Data collected in the main study in School D, E and F are presented in the following order: (1) teachers' responses using the questionnaire data are intended to reveal teachers' perceptions, experiences and attitude toward noise inside their mathematics classroom, and also the surrounding noise from outside the classroom and school premises; (2) data related to the level of classroom noise in a classroom environment without the SNR device and thereafter with the SNR device in Schools D, E and F; (3) data related to learners' mathematics errors committed in a classroom environment controlled by the SNR device compared to the errors made without the SNR device in their mathematics classrooms; and, (4) data of learners' responses relating to their experience as they responded to the post-test learners test in a classroom environment of 70 to 80 dBA.

5.4.1. Main study teacher questionnaire responses

The questionnaire aimed to elicit responses from the Grade 10 mathematics teachers. In this regard, teachers' responses would relate to their overall perceptual understanding and attitudes toward the level of noise inside and outside mathematics classrooms. Teachers were asked to rate their responses on the Likert scale from 1-7 to indicate the extent to which they experienced the noise while teaching a Grade 10 mathematics class (Appendix D). The Table 5.3 presents teachers' responses in schools D, E and F.

Table 5.3: Main study teacher questionnaire responses

	Max. code	7	6	5	4	3	2	1	Mean range
		Always	Very frequently	Frequently	Occasionally	Rarely	Very rarely	Never	
	Likert scale range	$6 < r \leq 7$	$5 < r \leq 6$	$4 < r \leq 5$	$3 < r \leq 4$	$2 < r \leq 3$	$1 < r \leq 2$	$0 < r \leq 1$	
Experiences learners' noise			E	F			D		4,3
Learners noise turns out to be disruptive behaviour.			E		F	D			4,3
Learners' noise turns out to affect fellow learners' concentration.			E	F			D		4,3
Losing the teaching time because of learners' noise		F	E					D	4,7
Failing to achieve the lesson objective because of learners' noise					E	F		D	2,7
Feeling irritated because of learners' noise				E		F	D		3,3
The noise coming from outside the school premises affecting the lesson					D E		F		3,3
The noise coming from inside the school premises affecting the lesson					D E		F		3,3
Ignoring the learners' noise and carry on with the lesson				E				D F	2,3
Learners complaining that they can't hear the teacher because of the level of noise			F			E		D	3,3

The mean responses of teachers' questionnaire show the extent to which teachers were affected by noise in their practice.

Teachers mentioned that they frequently lost some of their teaching time because of learners' noise. On frequent occasions, teachers mentioned that they experienced learners' noise in their classrooms, that learners' noise also turned out to be disruptive behaviour and that it frequently affected the concentration of their fellow learners.

The following happened occasionally: teachers' feeling irritated because of learners' noise during their mathematics lessons and learners' complaining that they cannot hear the

teacher because of the noise level. Noise from inside and outside the school premises also occasionally affected their lesson delivery.

On rare occasions teachers would fail to achieve the lesson objective because of learners' noise, while on very rare occasions, teachers would ignore learners' noise and carry on with the lesson.

5.4.2. Data related to the level of classroom noise level for the main study

Data related to learners' noise level trend in each mathematics classroom for the main study were measured using a SLM with the noise level software. The instant noise level in dBA was captured every two seconds and instantly changed into a graph. The use of the noise level software and the recording of the instant noise every two seconds increased the data validity and reduced the recording of errors that may have resulted from manual recording.

In the main study, data of classroom noise level, with and without the SNR device, were captured in the same lesson. In the first part of the lesson, the SNR device was installed in the classroom. About halfway through the lesson, the SNR device was switched off. Alternatively, if during the first part of the lesson there was no SNR device in the classroom, about halfway during the lesson the SNR device would be installed.

The noise level in schools D, E and F is presented in the next section. Data were taken by the SLM and analysed by the noise level software.

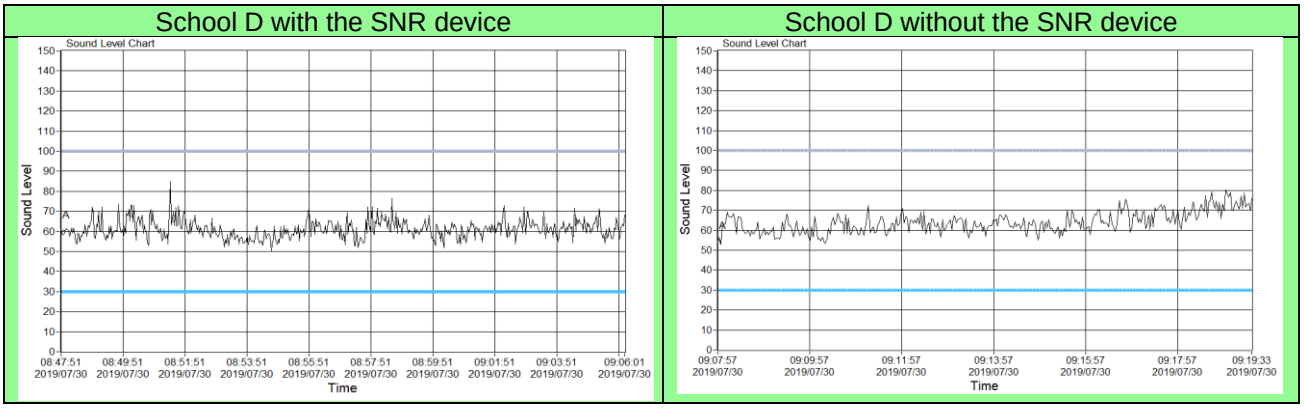
5.4.2.1. Noise level in school D

School D was located in the suburb of Johannesburg and the Grade 10 mathematics class had 28 learners on the class register. The data about classroom noise level were taken while the class was having a discussion on financial mathematics, more specifically about the exchange rate. The SNR device was first installed in the classroom and switched on. About halfway through the lesson the SNR device was switched off. The following are the sequences of the lesson:

- From 08:48 – 09:02, the teacher explained the concepts about buying power of a strong currency and a weak currency.
- From 09:02 – 09:09, the learners were assigned work to perform as a group at 9:06 while learners are still busy with group work, the SNR device was switched off and remained off until the end of the lesson.
- From 09:09 – 09:17, the teacher effected corrections with the learners.
- From 09:17 – 09:20, learners were given a question to work out alone, the time of the lesson ended while the learners were still working individually, and the teacher gave them other questions similar to the previous example as homework. The observation shows that learners seemed to be engaged in their learning.

At some point during teacher's corrections, a helicopter passed by and the noise could be heard for about five seconds. The instant noise level recorded 78 instant dBA. Learners did not seem to have been bothered or seemed to have noticed the passing helicopter. Neither did the teacher stop talking. The researcher concluded that for a short period, instant noise might not affect learning. The next graph represents the noise level in school D in the main study.

Figure 5.17: Noise level (dBA) trend in School D



The average with the SNR device was 61,1 dBA with 543 data collected while the average without the SNR device was 64 dBA for 348 data collected. This shows that without the SNR device, the noise increased by 5%.

5.4.2.2. Noise level in School E

School E was located in older building infrastructure around the City of Johannesburg metropolitan area and the mathematics class had 35 learners on the class register. The noise level data without the SNR device in the classroom was taken first and followed by the use of the SNR device in the classroom. The class was involved in the topic of statistics and they discussed how to summarise a set of data using a five-number summary.

- From 10:17 – 10:26: Learners were doing class exercise on their own. At least four learners were speaking to each other and were disengaged. Three learners called out the answers to their friends.

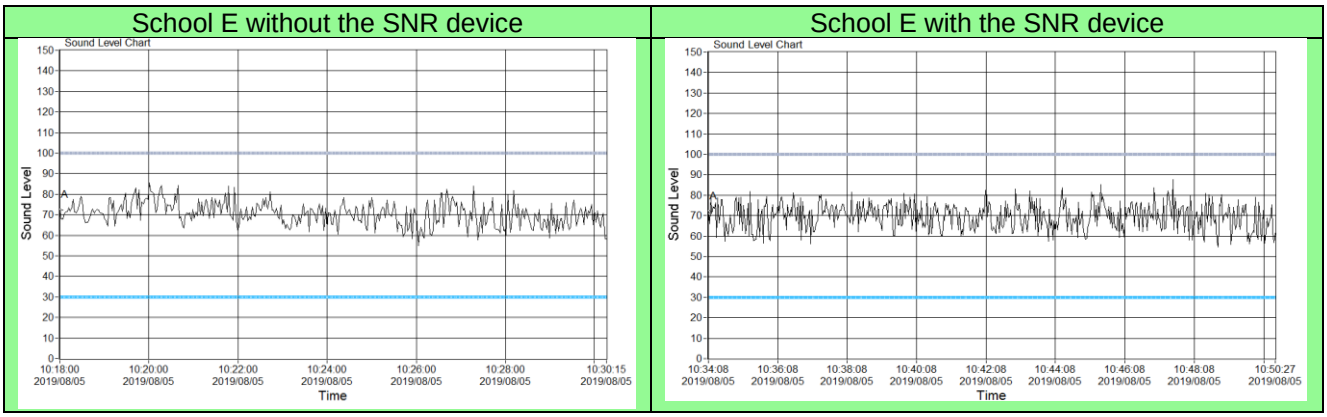
- At 10:28, a learner coughed out with the intention to clear the throat and fellow learners reacted with an amusement noise (momentarily noise of 74 dBA). This shows how much unintentional action from a learner may cause a rise of classroom noise level (if other learners are not fully engaged in the lesson).

- From 10:26 – 10:31: The teacher asked a learner to go in front of the class and to do correction on the board. The majority of learners were not paying attention to the correction, as they were having their own discussion.

- From 10:33 – 10:38: As another learner went to do a correction on the board, the SNR was installed and switched on, the noise level was set on the classwork. During this exploration phase, the device kept showing yellow most of the time (see, Section 5.2.3). After installing the SNR device, the noise subsided and more learners seemed to pay attention to the fellow learner doing correction on the board.

- From 10:38 – 10:50, the teacher further explained the five-number summary and continued the lesson by showing the learners how to plot the five-number summary on the “box and whisker diagram”. Learners seemed to be paying attention as indicated by the average dBA. The noise level was reduced.

Figure 5.18: Noise level (dBA) trend in School E



The average without the SNR device was 70,5 dBA with 367 data collected while the average with the SNR device was 69,6 dBA for 368 data collected. This shows that with the SNR device, the noise decreased about 1%.

5.4.2.3. Noise level in school F

School F was located in near the railway line around the City of Johannesburg metropolitan area and the mathematics class had 43 learners on the register.

The teacher left the class to attend a meeting. The teacher left the class in the care of a learner who had been appointed as a class representative from the Representative Council of Learners (RCL). The RCL learner who took charge of the class acted as a facilitating teacher. The learner assisted by effecting corrections of previous homework on algebra and the topic was solving exponential equations.

The RCL learner would ask one of the classmates to choose a question that they found difficult. The RCL learner or teacher assistant would write an equation on the board. After writing the question, the teacher assistant would ask volunteers to raise their hands. The RCL learner then would choose one learner to go to the front, and to demonstrate on the board how to solve the problem. Fellow learners would silently follow along and if an error was noted while a learner was solving the equation, they would wait until she or he reached the final answer. The RCL learner would ask if the answer was correct or not. If the answer was incorrect, another volunteer went in front to do it better. If the answer was

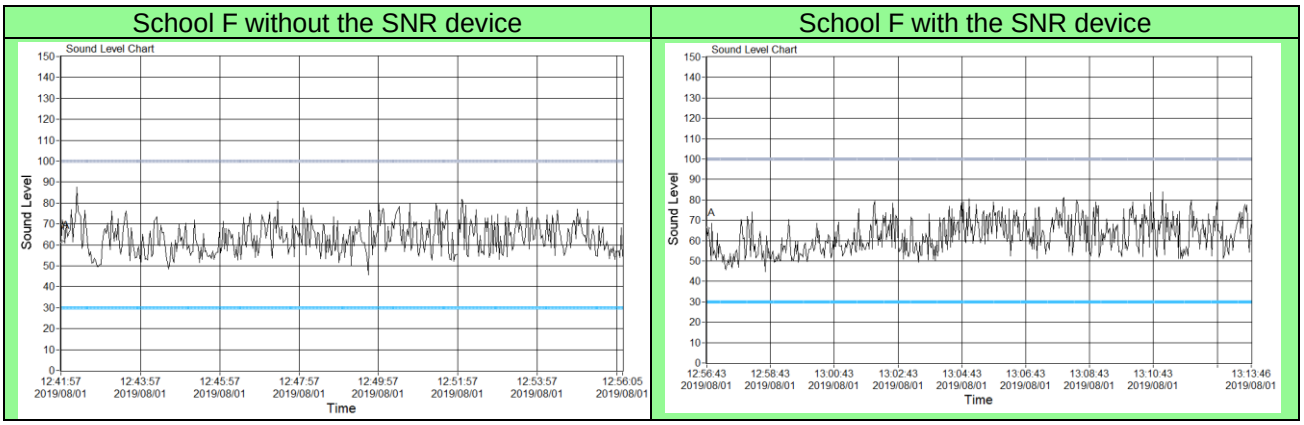
correct, the RCL learner would ask fellow learners to choose another question. For the duration of the whole lesson, the same pattern was followed, and the lesson seemed to flow smoothly, without unnecessary interruptions.

There was a moment when the noise level increased, but it felt as if it was a noise of wanting to participate and getting involved in the learning rather than non-productive noise. For example, there was a rise of the noise level when more learners wanted to suggest the question number that had to be done next. In addition, when more learners were eager to volunteer to go to the board while the RCL learner could only choose one learner, those who were not selected felt disappointed to a certain level, and their disappointment momentarily raised the classroom noise. Other moments of noise came about when one learner suggested that she knew a quicker method than the one used on the board.

The SNR device was positioned in the classroom for the duration of the lesson.

From the beginning of the lesson to halfway through the lesson (12:40 to 12:56), the SNR device was switched off. From halfway through the lesson until the end of the lesson (12:57 to 13:20), the SNR device was switched on. The noise level data in Figure 5.19 shows that the noise level subsided at a certain point when the SNR device was switched on.

Figure 5.19: Noise level (dBA) trend in school F



The average without the SNR device was 63,5 dBA with 423 data collected while the average with the SNR device on was 62,3 dBA for 510 data collected. This shows that with the SNR device, the noise decreased about 2%.

5.4.3. Data related to mathematics errors in the main study

Learners wrote three types of mathematics achievement tests in a classroom environment with a high level of noise, and thereafter in a normal environment with a noise level that was conducive to learning. Algebra questions were intended to test the dissimilarities of learners' cognitive and thinking abilities when they were involved in learning mathematics topics with abstract contents. In contrast, geometry questions were intended to test learners' performance when involved in learning mathematics topics with concrete content. Mental mathematics calculations were intended to test learners' listening skills and their ability to process and recall information in a short period of time in two different noise learning environments.

The tests were administered to learners in the classroom with the noise environment ranging from 70 to 80 dBA. To maintain this level of noise in the classroom, local and popular songs were played, amplified to 70 to 80 dBA and monitored by the SLM. The rational of playing the music instead of creating other kind of noise in the classroom was to comply with research ethics (Section 4.9). In addition, the type of music played was helpful in eliminating extraneous variables that could have affected the internal validity of the study such as tiredness and stress (Section 4.6.3.3). Whenever the classroom noise

level needed to be regulated, the SNR device was used and the sound meter monitored that the noise was ranging from 50 to 60 dBA.

These observations motivated the researcher to change the sequence in which the tests were administered to the learners in the main study. In the main study in schools D, E and F, the learners first wrote the test in the environment controlled by the SNR device with the noise ranging from 50 to 60 dBA (see, Table 5.1). Thereafter, they wrote the test in a noisy environment with the music amplified to 70 – 80 dBA (see, Section 4.5.2.4).

From the pilot study, the researcher noticed another limitation which may have influenced the interpretation of the data. In the test written in a noisier environment, learners produced more errors and failed to attempt many questions. The researcher wondered whether these errors were the results of the noise factors only, and wanted to explore the phenomenological thinking that caused learners to make so many errors. To that effect, the researcher included the post-test questionnaire for learners to complete every time they wrote a test in a noise-induced classroom environment.

5.4.3.1. Learners' errors in the algebra test in the main study

The researcher used the algebra test to determine how learners used their mental process when performing tasks with abstract contents, in two different noise learning environments. The tests were designed to uncover the extent to which learners' cognitive thinking was affected by the noise level inside the classroom. Cognitive thinking requires that learners be able to comprehend, process, remember, and apply the information. The algebra test was designed to assess learners' comprehension of the question, assess the extent to which they remember the algebraic rules, process the rules, and apply the information to evaluate and solve the problem (see, Appendices A_1 & A_2).

The tests were administered to learners in Grade 10 learners in a school located in three different settings (Section 4.3.1.3). In marking the learners' tests, the researcher followed the marking guidelines (Appendices A_1 & A_2). Nominal numbers were used to represent types of errors. Any correct answer or any correct step leading to a correct answer was marked with a digit 1. Any attempt to answer the question or any incorrect step leading to

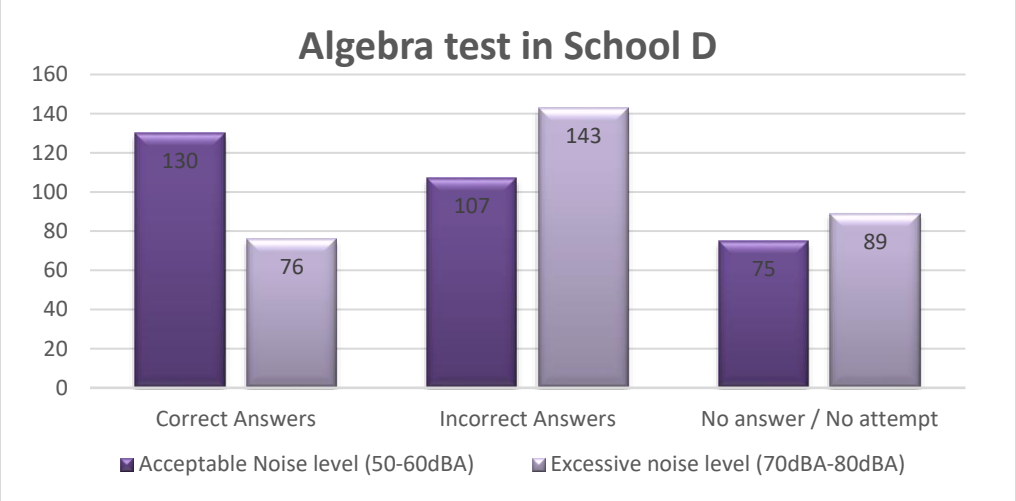
an incorrect answer was marked with a digit 2. Any section of the question which is not answered was marked with a digit 3.

The following sections present the data related to errors made by learners in the algebra test in the pilot study in schools A, B and C, in the main study in schools D, E and F and learners' post-test responses.

5.4.3.1.1. Learners' errors in algebra test in School D

School D was located in a suburb of Johannesburg. The tests were administered to Grade 10 learners (Section 4.3.1.3.1). The next graph represents the results of school D's algebra test.

Figure 5.20: Learners' errors in the algebra test in School D



In a classroom environment with acceptable noise level, learners scored 130 correct answers. Conversely, in the uncontrolled noise classroom environment, learners scored 76 correct answers. This accounted to an increase in accuracy of 42%.

In a classroom environment with an acceptable noise level, learners produced 107 incorrect answers, and in an uncontrolled noise classroom environment, learners made

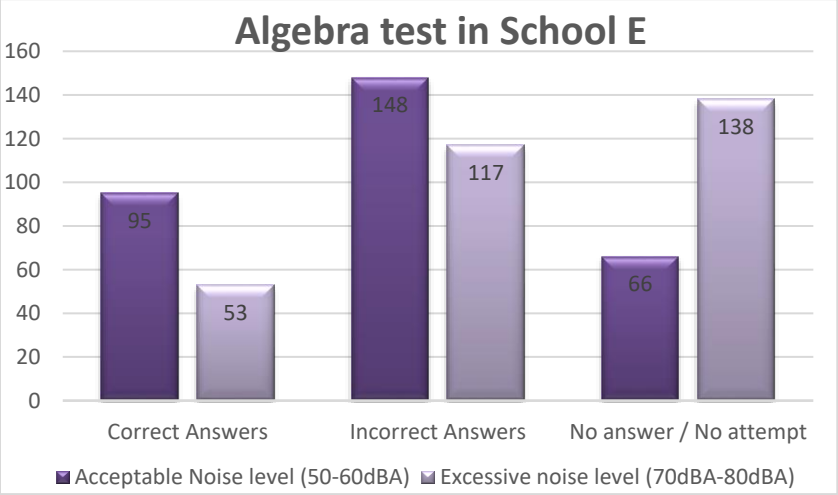
143 incorrect answers. This indicates that by increasing the noise, the incorrect answers also increased by 34%.

In a classroom environment with an acceptable noise level, learners made no attempt to answer 75 questions, and in an uncontrolled normal noise classroom environment, learners made no attempt to answer 89 questions. This means that classroom noise increased learners' tendencies of not attempting to do questions by 19%.

5.4.3.1.2. Learners' errors in the algebra test in School E

School E was one of the sampled schools located in the older building structure. The school was over 100-years-old and located in the City of Johannesburg metropolitan area (see, Section 4.3.1.3.3). The next graph represents the results in School B's algebra test.

Figure 5.21: Learners' errors in the algebra test in School E



In the classroom environment with an acceptable noise level, learners scored 95 correct answers. Conversely, in the uncontrolled noise classroom environment, learners scored 53 correct answers. This accounts for an increase in accuracy of 44%.

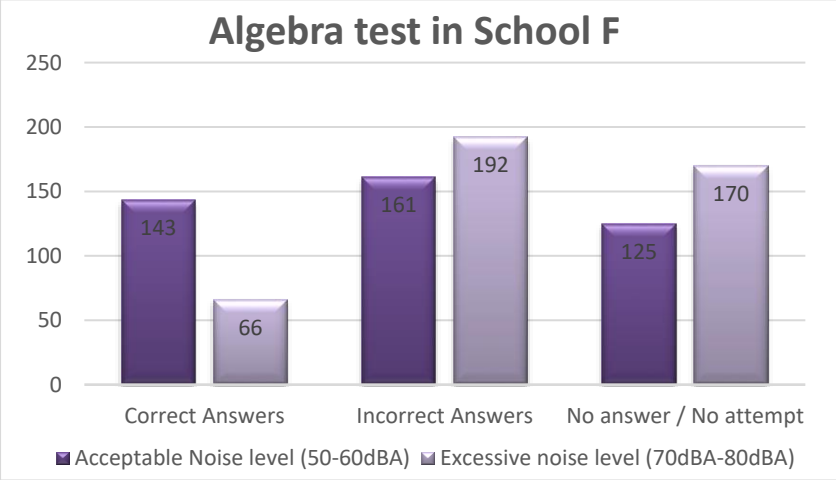
In the classroom environment with acceptable noise level, learners made no attempt to answer 66 questions, and in an uncontrolled normal noise classroom environment, learners made no attempt to answer 138 questions. This means that classroom noise increased learners' tendencies of not attempting to do questions by 109%.

In the classroom environment with acceptable noise level, learners produced 148 incorrect answers, and in an uncontrolled noise classroom environment, learners produced 117 incorrect answers. This indicates that by increasing the noise, the incorrect answers decreased by 21%. By simply looking at the number of the percentage decrease, the data may seem to suggest that the increase of learners' noise level, the incorrect answers from learners is also decreased. But, a close look at the 109% increase of questions that were not answered, it may be reasonable to say that learners did not get more incorrect answers because they did not attempt the questions.

5.4.3.1.3. Learners' errors in algebra test in School F

School F was one of the sampled schools located next to the railway line in the City of Johannesburg metropolitan area (Section 4.3.1.3.3). The next graph represents the results of School F's algebra test.

Figure 5.22: Learners' errors in the algebra test in School F



In the classroom environment with an acceptable noise level, learners scored 143 correct answers. Conversely, in the uncontrolled noise classroom environment, learners scored 66 correct answers. This accounts to an increase in accuracy of 54%.

In the classroom environment with an acceptable noise level, learners produced 161 incorrect answers while in an uncontrolled noise classroom environment, learners

produced 192 incorrect answers. This indicates that by increasing the noise, the incorrect answers were increased by 19%.

In the classroom environment with an acceptable noise level, the learners made no attempt to answer 125 questions, and in an uncontrolled normal noise classroom environment, learners made no attempt to answer 170 questions. This means that classroom noise increased learners' tendencies of not attempting to answer questions by 36%.

The next data show the total combined data in the algebra test in six schools that participated in the study.

5.4.3.2. Errors in basic and mental calculations in the main study

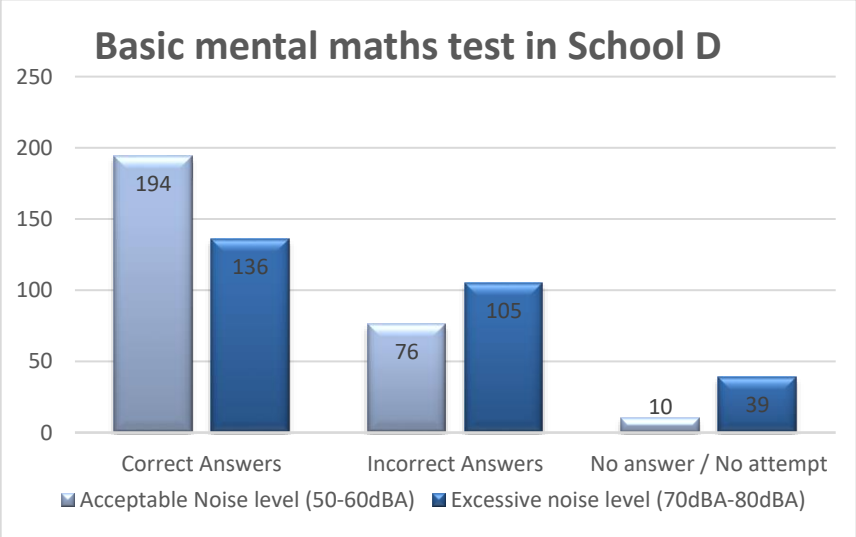
This study used simple and basic mental mathematics calculations for the Grade 10 level. Questions 1 and 2 of the test were designed to test learners' listening skills. The other remaining eight questions were intended to test learners' ability to process and recall information over a short period of time in two different noise learning environments.

Section 5.4.3.2.1 presents the data related to errors produced by learners in the basic and mental tests in different schools. Thereafter, learners' post-test responses are presented.

5.4.3.2.1. Learners' errors in the basic and mental mathematics test in School D

School D was located in the suburb of Johannesburg. The tests were administered to learners in Grade 10 (Section 4.3.1.3.1). The next graph represents the results in school D in the basic and mental mathematics test.

Figure 5.23: Learners' errors in basic and mental mathematics test in School D

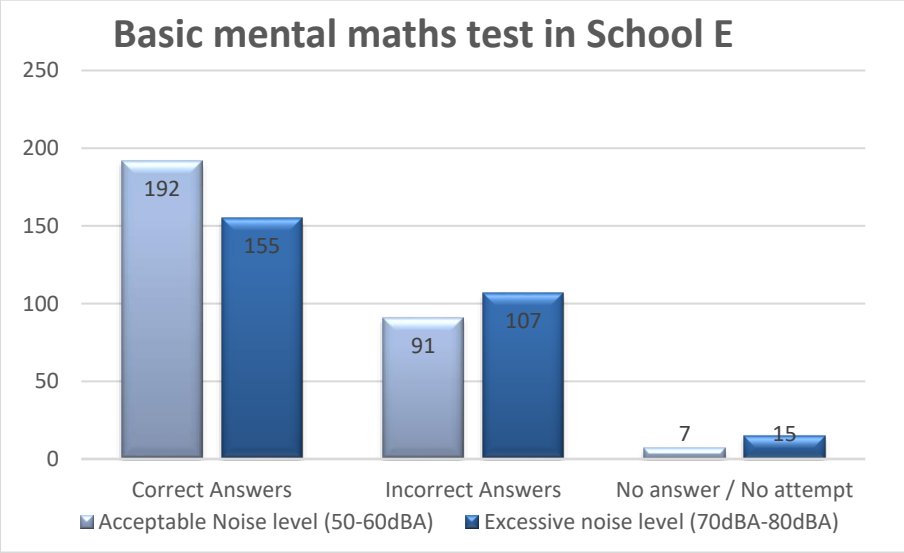


In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners made 194 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 136 correct answers. This indicates that the increases of the noise in the classroom decreased the correct answers by 30%. In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 76 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 105 incorrect answers. This indicates that the increase of the noise in the classroom also increased the number of incorrect answers by 38%. In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt ten questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt to answer 39 questions. This indicates that by controlling the noise, learners were encouraged to attempt to answer many questions by 290%.

5.4.3.2.2. Learners' errors in the basic and mental mathematics test in School E

School E was one of the sampled schools located in an older building structure. The school was over 100-years-old in the City of Johannesburg metropolitan area (Section 4.3.1.3.3). The next graph represents the results in School E's basic and mental mathematics test.

Figure 5.24: Learners' errors in the basic and mental mathematics test in School E



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 192 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 155 correct answers. This indicates that the increase of noise in the classroom decreased the correct answers by 19%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners made 91 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 107 incorrect answers. This indicates that the increase of the noise in the classroom also increased the incorrect answers by 55%.

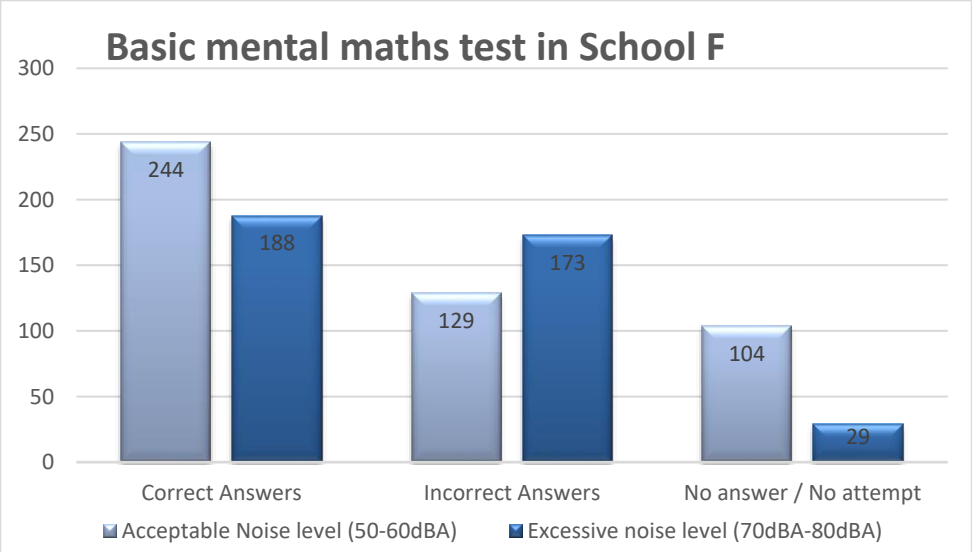
In the classroom environment controlled by the SNR device, with the noise level ranging from 50 to 60 dBA, learners failed to attempt to answer seven questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt to answer 15

questions. This indicates that by controlling the noise, learners were encouraged to attempt to answer many questions by 114%.

5.4.3.2.3. Learners' errors in the basic and mental mathematics test in School F

School F was one of the sampled schools located near the railway line in the City of Johannesburg metropolitan area (Section 4.3.1.3.3). The next graph represents the results in school F in the basic and mental mathematics test.

Figure 5.25: Learners' errors in the basic and mental mathematics test in School F



In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 244 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 188 correct answers. This indicates that the increase of noise in the classroom decreased the number of correct answers by 23%.

In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 129 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 173 incorrect answers. This indicates that the increases of the noise in the classroom also increased the number of incorrect answers by 34%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 – 60 dBA, learners failed to attempt 16 questions. In the classroom environment

with a noise level of 70 – 80 dBA, learners failed to attempt 29 questions. This indicates that by controlling the noise, learners were encouraged to attempt many questions by 81%.

5.4.3.3. Errors in the Euclidean geometry test in the main study

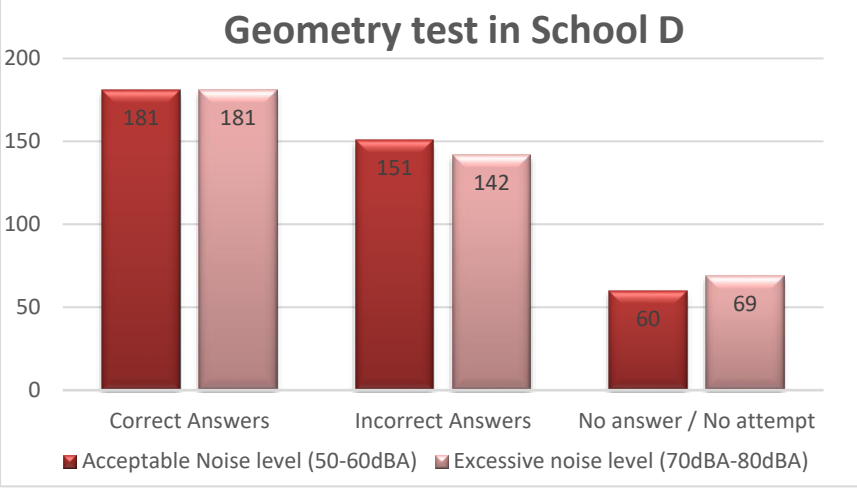
This study used Euclidean geometry questions on the topics that Grade 10 learners had already covered in the previous grades. The questions in the geometry test were designed to test learners' performance using their sense of vision as far as concrete learning was concerned. Learners needed to see the different angles in triangle and parallel lines, formulate a statement with reasons and solve to find the size of angles. Errors produced by learners during these Euclidean geometry tests were used to determine the extent to which the two contrasting noise learning environments affected learners' sense of vision and recall of the riddles.

Section 5.4.3.3.1 presents the data related to errors made by learners in the Euclidean geometry test in different schools. Thereafter, learners' post-test responses will be presented.

5.4.3.3.1. Learners' errors in the Euclidean geometry test in School D

School D was located in the suburb of Johannesburg. The tests were administered to learners in Grade 10 learners (Section 4.3.1.3.1) The next graph represents the results in School D's Euclidean geometry test.

Figure 5.26: Learners' errors in the Euclidean geometry test in School D



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 181 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 181 correct answers. This indicates that learners' performance in this school in classroom environment was even.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 151 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced 142 incorrect answers. This indicates that the increase of the noise in the classroom slightly decreased the incorrect answers by 5%.

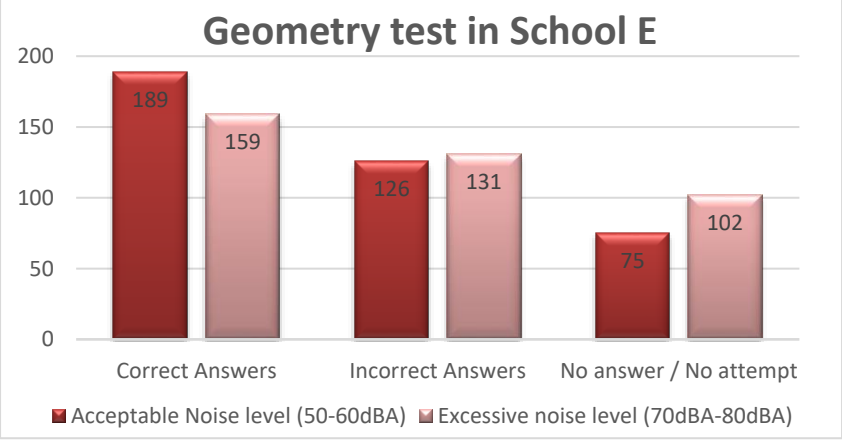
In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt to answer 60 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt to answer 69 questions. This indicates that by controlling the noise, learners were slightly encouraged to attempt questions by 15%.

The overall performance in School's D geometry test seems to be even.

5.4.3.3.2. Learners' errors in the Euclidean geometry test in School E

School E was one of the sampled schools located in an older building structure (over 100-year-old) in the City of Johannesburg metropolitan (Section 4.3.1.3.3). The next graph represents the results in School E's Euclidean geometry test.

Figure 5.27: Learners' errors in the Euclidean geometry test in School E



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 189 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored a total of 159 correct answers. This indicates that the increases of the noise in the classroom decreased the number of correct answers by 16%.

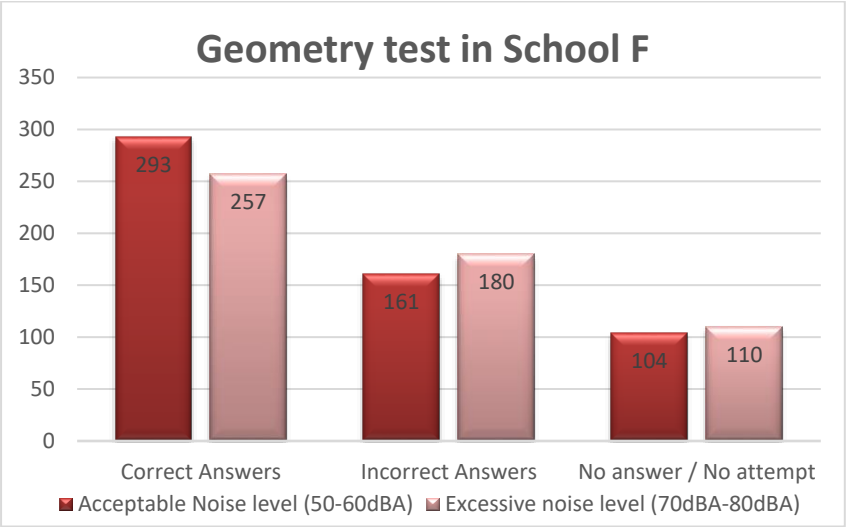
In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 126 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced 131 incorrect answers. This indicates that the increase of noise in the classroom slightly increased the number of incorrect answers by 4%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt to answer 75 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt to answer 102 questions. This indicates that by controlling the noise, learners were encouraged to attempt many questions by 36%.

5.4.3.3.3. Learners' errors in the Euclidean geometry test in School F

School F was one of the sampled schools located near the railway line in the City of Johannesburg metropolitan area (Section 4.3.1.3.3). The next graph represents the results of School F's Euclidean geometry test.

Figure 5.28: Learners' errors in the Euclidean geometry test in School F



In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 293 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored 257 correct answers. This indicates that the increase of the noise in the classroom decreased the number of correct answers by 12%.

In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 161 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced 180 incorrect answers. This indicates that the increase of noise in the classroom also increased the number of incorrect answers by 12%.

In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt to answer 104 questions. In the classroom environment with a noise level of 70 – 80 dBA, learners failed to attempt to answer 110 questions. This indicates that by controlling the noise, learners were encouraged to attempt to answer many questions by 6%.

5.4.3.4. Findings of learners' post-test questionnaire

The need to use the post-test questionnaire became significant after the analysis of the pilot study data of learners' mathematics tests. The researcher noticed that the absence

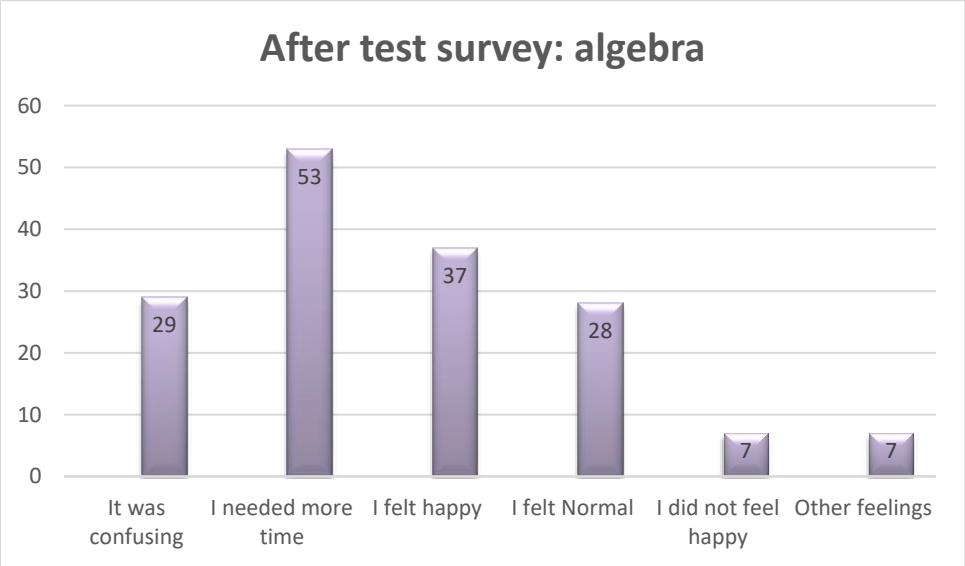
of learners' post-test questionnaire posed some limitations. For instance, without learners' survey, there was a challenge to establish whether other confounding variables influenced learners' performance in the mathematics achievement tests at that particular moment. In addition, even if the excessive noise level was the influencing variable, the researcher needed to know particular inconveniences that learners faced when solving mathematics achievement tests in an environment with an excessive classroom noise level. Learners were asked to tick (✓) the correct phrase that represented their experience during each mathematics test.

Every time that a test was written in a noisy environment of 70 to 80 dBA, learners immediately completed a survey form. Therefore, learners' experiences and feelings were captured instantaneously. The following are learners' responses from the post-test questionnaires.

5.4.3.4.1. Learners' post-test questionnaire for the algebra test

Learners in schools D, E and F wrote an algebra test in the classroom environment with a noise level of 70 to 80 dBA. To produce a noise level in the range of 70 to 80 dBA, learners' popular songs were played in the classroom. The next graph represents learners' responses after the algebra test in a classroom environment with an excessive noise level.

Figure 5.29: Learners' post-test questionnaire for algebra



Out of 161 responses, 53 learners indicated that they needed more time and 29 learners indicated that it was confusing to solve algebraic problems in an excessively noisy environment. Even though there was an excessive noise level, 37 out of 161 responses from the learners indicated that they felt happy and 28 felt that it was normal to work in such an environment. The researcher attributes such feelings of happiness and feeling normal to the fact that the noise that was used was music. The general sensation of music was making learners feel happy and normal.

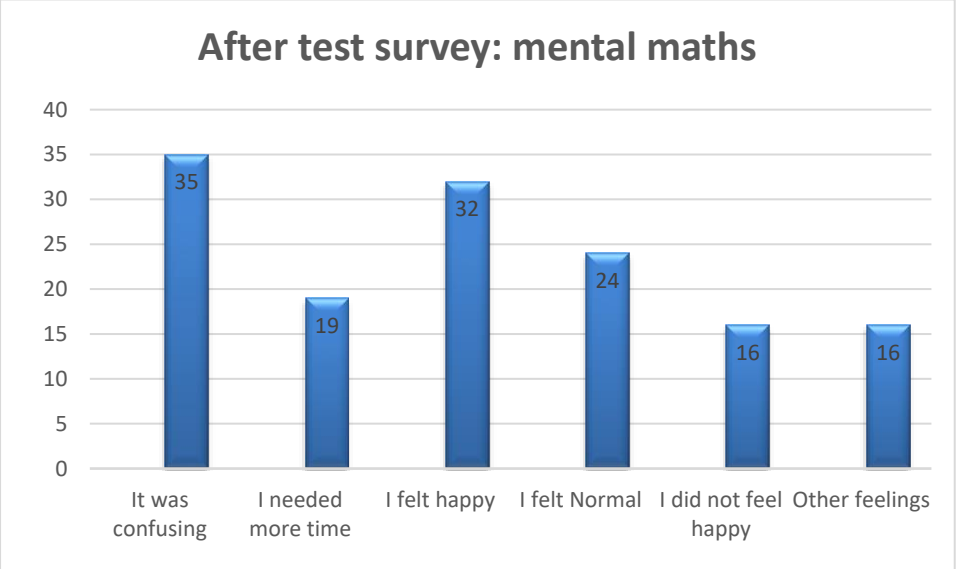
Seven learners indicated that they did not feel happy to solve algebraic problems in an excessively noisy environment.

Seven remaining responses indicated other feelings to which the learners responded: I forgot; distracting; I could not concentrate; I was distracted by music; frustrating and stressful; I wanted to dance and sing along; and I was cool, nice.

5.4.3.4.2. Learners' post-test questionnaire for the basic and mental calculation test

Learners in schools D, E and F wrote a test in mental and basic calculations in the classroom environment with a noise level of 70 to 80 dBA. To produce a noise level in the range of 70 to 80 dBA, learners' popular songs were played in the classroom. The next graph represents learners' responses following the mathematics mental and basic calculations test in a classroom environment with an excessive noise level.

Figure 5.30: Learners' post-test questionnaire in mental mathematics



Out of 142 responses, 35 learners indicated it was confusing and 19 learners indicated that they needed more time to do mental and basic mathematics calculations in an excessively noisy environment.

As basic mathematics calculations do not require much of cognitive demand, 32 out of 142 responses from the learners indicated that they felt happy while 28 felt that it was normal to work in such an environment. The researcher attributes such feelings of happiness and feeling as normal since the noise used was music. The general sensation of music is that it makes people feel happy and normal.

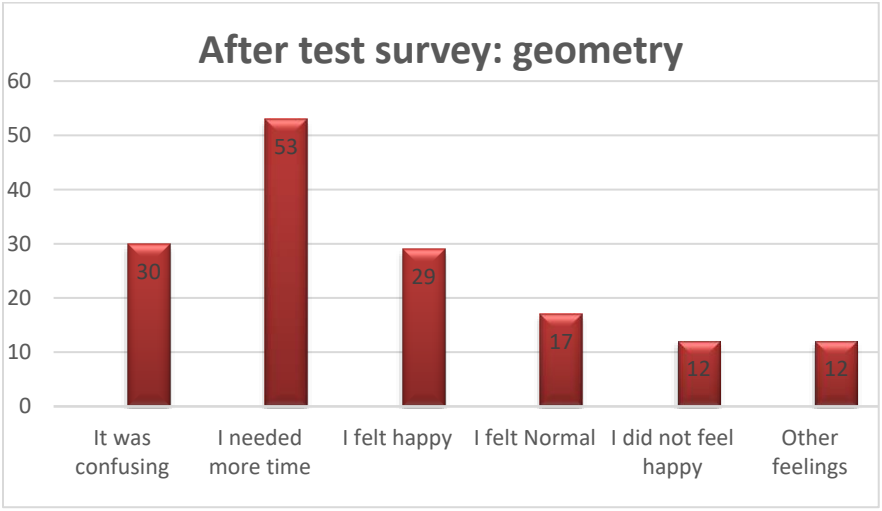
Sixteen learners indicated that they did not feel happy to do mental and basic mathematics calculations in an excessive noise environment.

The 16 remaining responses indicated other feeling learners had saying: six out of all those who express other feelings mentioned that they could not hear many questions that were read out in a noise-induced environment out of learners who could not hear the questions. They further indicated that they felt angry while one learner felt bored. Two responses said that it was nice, one response was that it made the work easier, another responded by indicating that music evoked feelings of wanting to dance and sing along.

5.4.3.4.3. Learners' post-test questionnaire for the Euclidean geometry test

Learners in school D, E and F wrote a test in Euclidean geometry in the classroom environment with a noise level of 70 to 80 dBA. To produce a noise level in the range of 70 to 80 dBA, learners' popular songs were played in the classroom. The next graph represents learners' responses subsequent to the Euclidean geometry test in a classroom environment with an excessive noise level.

Figure 5.31: Learners' post-test questionnaire in geometry



Out of 153 responses, 53 learners indicated that they needed more time while 30 learners indicated that it was confusing to solve angles and formulate reasons behind the statements in Euclidean geometry while the environment was excessively noisy. Even though there was an excessive noise level, 29 responses from the learners indicated that they felt happy while 17 learners felt it was normal to work in a noise-induced environment. Twelve learners indicated that they did not feel happy to do Euclidean geometry in an excessively noisy environment.

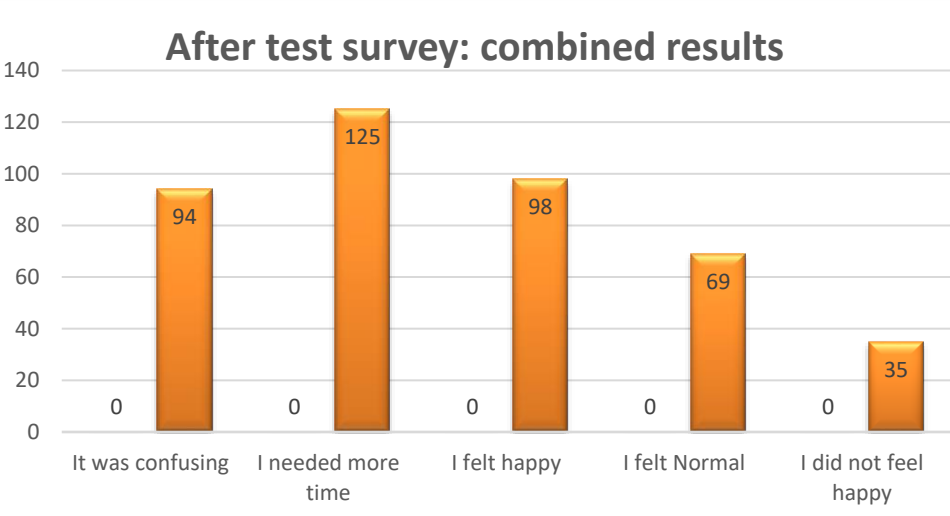
Twelve remaining responses indicated other feeling from the learners. The twelve remaining learners seemed to have mixed feelings: Some learners said that it was cool, amazing, and that the music was well controlled, and one learner acknowledged that she (he) felt normal at some point. However, two responded saying that the music was distracting.

Three responded by using specific adjectives to show that they were not happy to do Euclidean geometry in an excessively noisy environment saying: “I was bored, furious and excruciated”.

5.4.3.4.4. Learners’ post-test questionnaire for combined test results

This section combined all learners’ responses from the post-test questionnaire. The survey slip was completed by each participant or respondent to the algebra, Euclidean geometry and basic and mental mathematics tests. All the learners’ responses across all schools from different backgrounds were combined. The purpose was to determine learners’ dominant feeling about excessive noise across all cognitive levels of learning mathematics.

Figure 5.32: Learners’ post-test questionnaire combined results



Out of 421 learners’ responses, 125 learners (about 29.7% of all responses) indicated that they needed more time. The second most dominant feeling related to the 98 responses by learners (about 23.3% of all respondents) who felt happy. The third dominant feeling among learners was from the 94 responses (about 22.3% of all respondents) who indicated that it was confusing to work in an excessive noisy learning environment. About 16.4% of all respondents (69 out of 421 responses) indicated that they felt normal. About 8.3% (35 out 421 responses) indicated that they did not feel happy to work in an excessive noisy learning environment.

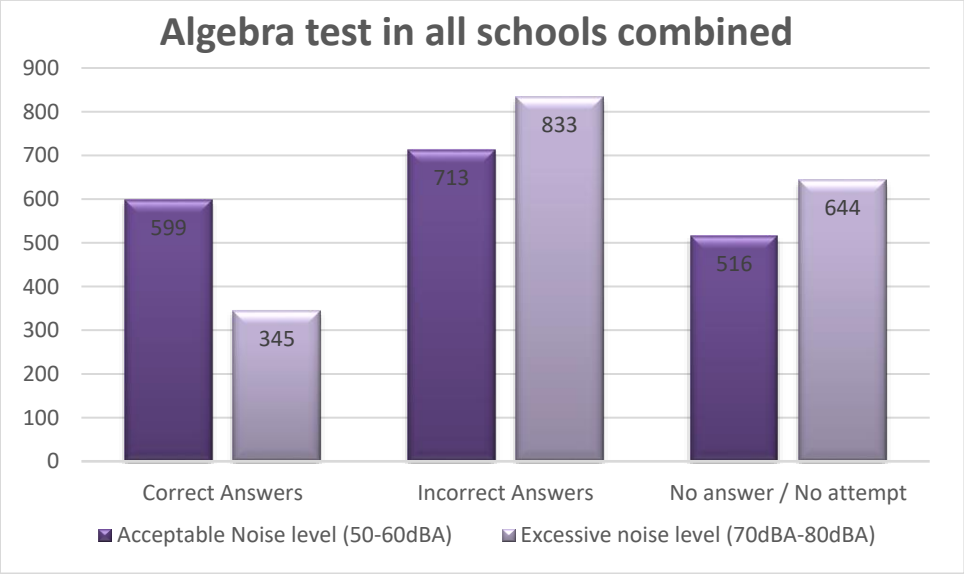
5.4.3.5. Mathematics errors: combined results

This section combined all learners' mathematics errors per topic. Participants from six schools with learners from different backgrounds wrote a test on various topics in an excessive noisy learning environment. The main purpose of grouping learners' errors per topic was to draw a conclusion on which topic was mostly affected by excessive noise when learning in mathematics.

5.4.3.5.1. Learners' errors in the algebra test in all six schools

Data of learners' errors in the algebra from all six Grade 10 mathematics classes were combined. The data present the general learners' performance in algebra in two classrooms' noise environments. First, the SNR device of 50 to 60 dBA controlled the classroom. The second classroom environment was capped to 70 to 80 dBA, which represents the day to day noise level in many classrooms. The next graph represents the results of all schools in the algebra test.

Figure 5.33: Learners' errors in the algebra test in all schools



In a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners scored a total of 599 correct answers. In the noisy

classroom environment of 70 to 80 dBA, learners scored 345 correct answers. This accounts for an accuracy increase of 42%.

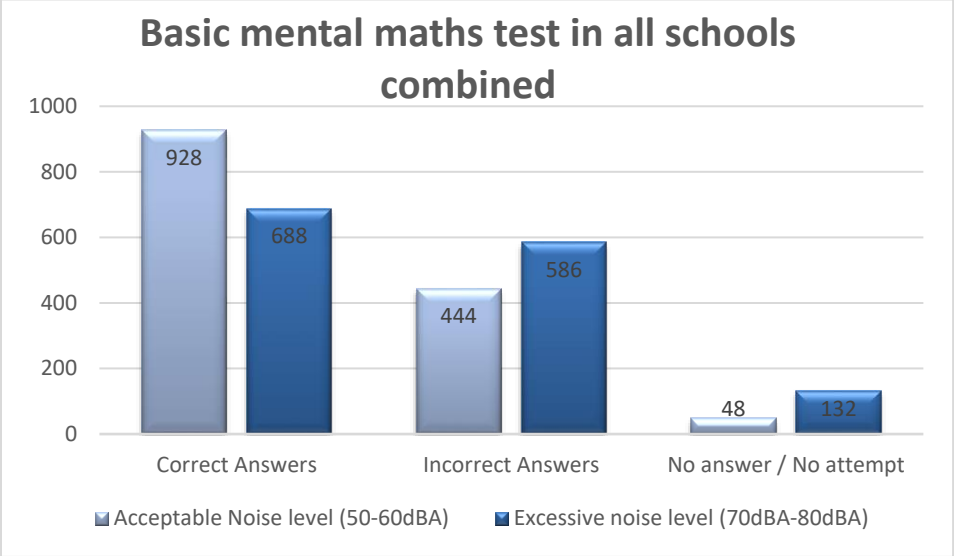
In a noise classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced 713 incorrect answers. In the noisy classroom environment of 70 to 80 dBA, learners produced 833 incorrect answers. This indicates that the increase of the noise in the classroom also increased the number of incorrect answers by 17%.

In the noise classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners made no attempt to answer 516 questions. Furthermore, in the noisy classroom environment of 70 to 80 dBA, learners made no attempt to answer 644 questions. This indicates that the increase of the noise in the classroom also increased learners' tendencies of not attempting to do questions by 36%.

5.4.3.5.2. Learners' errors in basic and mental mathematics achievement tests in all schools combined

Data related to errors made by learners in the basic and mental tests from all six Grade 10 mathematics classes were combined. The data give a general learners' performance in the basic and mental tests in two different classrooms noise environments. First, the SNR device of 50 to 60 dBA controlled the classroom. The second classroom environment was in the range of 70 to 80 dBA, similar to the day-to-day noise level in many classrooms. The next graph represents the results in all schools for the basic and mental tests.

Figure 5.34: Learners' errors in mental mathematics in all schools



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 928 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored a total of 688 correct answers. This indicates that the increase of the noise in the classroom decreased the correct answers by 26%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 444 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced a total 586 incorrect answers. This indicates that the increases of the noise in the classroom also increased the incorrect answers by 32%.

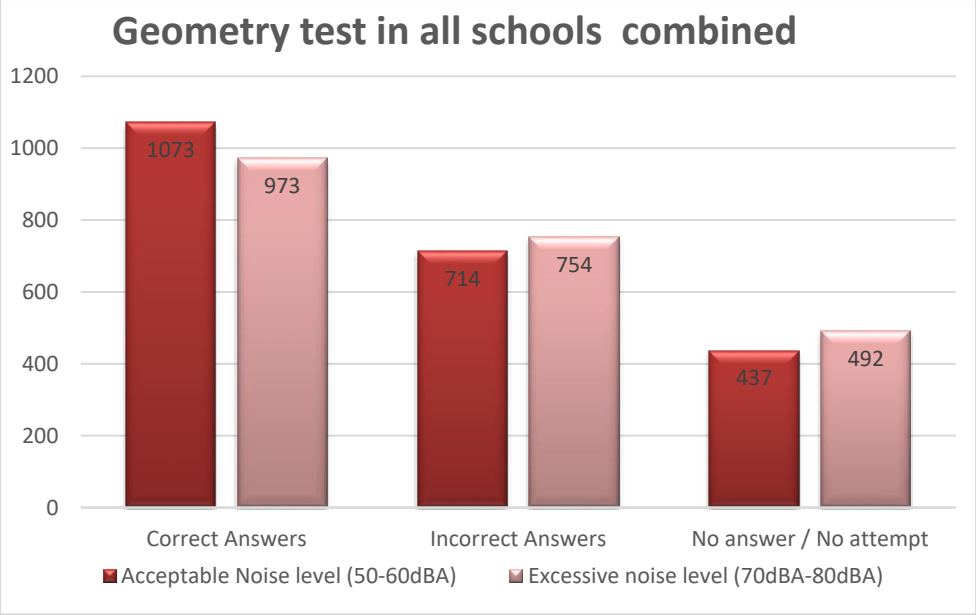
In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners failed to attempt 48 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt 132 questions. This indicates that by controlling the noise, learners were encouraged to attempt many questions by 132%.

5.4.3.5.3. Learners' errors in the Euclidean geometry test in all schools

Data related to errors made by learners in the Euclidean geometry tests from all six Grade 10 mathematics classes were combined together. The data yielded general learners'

performance in basic and mental tests in two different classrooms noise environments. First, the SNR device of 50 to 60 dBA controls the classroom. The second classroom environment was in the range of 70 to 80 dBA, similar to the day-to-day noise level in many classrooms. The next graph represents the results in all schools in the Euclidean geometry tests.

Figure 5.35: Learners' errors in geometry in all schools



In a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 1073 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored a total of 973 correct answers. This indicates that the increase of the noise in the classroom decreased the number of correct answers by 9%.

In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 714 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced a total of 754 incorrect

answers. This indicates that the increase of noise in the classroom also increased the number of incorrect answers by 6%.

In the classroom environment controlled by the SNR device with a noise level ranging from 50 to 60 dBA, learners failed to attempt to answer 437 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt to answer 492 questions. This indicates that by controlling the noise, learners are encouraged to attempt many questions by 13%.

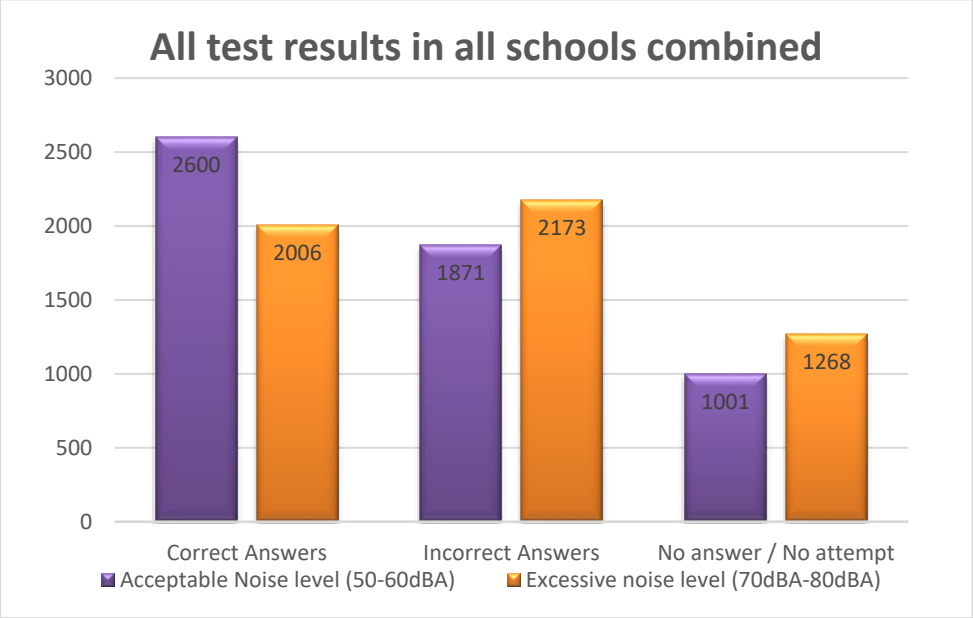
5.4.3.6. Learners' combined mathematics errors analysis

This section combines and analyses learners' errors in mathematics from the six schools. First learners' total errors in a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA are grouped in three categories correct answers, incorrect answers and No answers/ attempt. Second, learners' total errors in the classroom environment with a noise level of 70 to 80 dBA are also grouped in three categories: correct answers, incorrect answers and No answers/ attempt.

This procedure assisted in making conclusions on whether the SNR device was effective in increasing the level of learners' accuracy in the test, reducing the number of learners' incorrect answers in the test, or learners' attempts to answer questions.

In addition, learners' total errors analysis in mathematics is used to complement and support the hypothesis data analysis answering the main questions of the study.

Figure 5.36: Learners' errors in all tests across all schools



In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 2600 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored a total of 2006 correct answers. This indicates that the increase of the noise in the classroom decreased the number of correct answers by 23%. In the classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 1871 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners produced a total of 2173 incorrect answers. This indicates that the increase of the noise in the classroom also increased the number of incorrect answers by 16%. In the classroom environment controlled by the SNR device, with the noise level ranging from 50 to 60 dBA, learners failed to attempt to answer 1001 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners failed to attempt 1268 questions. This indicates that by controlling the noise, learners are encouraged to attempt many questions by 27%.

5.4.3.7. Hypotheses testing for total errors in mathematics tests

This section summarises approaches followed by the researcher to achieve reliable data on the use of the SNR device. The SNR device was used in the classroom and the noise

level was in the range of 50 to 60 dBA. When the SNR device was not used in the classroom, the noise level was in the range of 70 to 80 dBA. The approach sought to investigate a number of claims regarding the use of the SNR device in mathematics classrooms.

These hypothesis tests are intended provide a scientific and authentic basis to which the researcher will accept or reject the formulated null and alternate hypothesis regarding Grade 10 learners' performance in mathematics. The interpretation of the effects of the SNR device in mitigating learners' poor performance in the Grade 10 mathematics classroom needs a credible assessment to address the objectives of the research and the hypothesis formulated in Section 1.9. The effects of the SNR device in mitigating learners' poor performance in Grade 10 mathematics classroom is evaluated based on learners' error analysis in mathematics achievement tests written for algebra, basic and mental mathematics and Euclidean geometry. The analysis focused on the number of correct, incorrect and no responses that resulted within the environment with the SNR device, compared to the environment without the use of SNR.

Testing hypothesis 1

To guide the research methodology the study, the main hypotheses were formulated: alternative hypothesis [H_1] and the null hypothesis [H_0] (see, Section 1.9.1).

- H_1: The use of the SNR device during a mathematics lesson increases learners' accuracy in mathematics.
- H_0: The use of the SNR device during a mathematics lesson does not increase learners' accuracy in mathematics.

The analysis of variance (ANOVA) was used to test the relationship between learners' number of correct answers for tests that were written in different learning environments. First, when the SNR device was used in the classroom with a noise level range of 50 to 60 dBA. Thereafter, when the SNR device was not used in the classroom, the noise level was ranging from 70 to 80 dBA.

The study investigated whether the use of SNR device during classroom tests improved the performance of the learners about the number of correct answers learners scored in algebra, basic and mental mathematics and the Euclidean geometry test across six schools. Table 5.4 shows the results.

Table 5.4: ANOVA Test: Number of correct answers

		Sum of Squares	Df	Mean Square	F	P-value	Group Mean
Between groups		47.822	2	23.911	188.748	0.000	
Within groups		12.288	97	.127			
Group	With SNR						153
	Without SNR						118
Total		60.110	99				

Since the p-value (0.000) was less than 0.05 level of significance, the results show that there is statistical difference between the use of SNR device control in the mathematics study unit compared to when the device is not used. That is, the SNR device increased learners' accuracy in mathematics based on the number of correct answers produced by learners during mathematics tests.

Based on the p-value level of significance, the alternative hypothesis is accepted and the null hypothesis is rejected.

Testing hypothesis 2

To test whether the use of the SNR device in mathematics increased or decreased the ECL, the second hypotheses were formulated: alternative hypothesis [H_1] and the null hypothesis [H_0] (see, Section 1.9.2).

- H_1: The use of the SNR device during a mathematics lesson reduces learners' ECL in mathematics.
- H_0: The use of the SNR device during a mathematics lesson does not reduce learners' ECL in mathematics.

ANOVA was used to test the assumptions.

ANOVA was used to test the relationship between learners' number of incorrect answers for tests that were written in different learning environments. First, the SNR device was used in the classroom with a noise level ranging from of 50 to 60 dBA. Thereafter, the SNR device was not used in the classroom, and the noise level was ranging from 70 to 80 dBA.

The study investigated whether the use of SNR device during classroom tests reduced learners' ECL about the number of incorrect answers learners produced in the algebra, basic and mental mathematics and Euclidean geometry tests across six schools. The following ANOVA table shows the results.

Table 5.5: ANOVA Test: Number of incorrect answers

		Sum of Squares	Df	Mean Square	F	P-value	Group Mean
Between groups		68.808	2	34.404	733.060	0.000	
Within groups		4.552	97	.047			
Group	With SNR						110
	Without SNR						128
Total		73.360	99				

Since the p-value (0.000) was less than 0.05 level of significance, the results show that there is statistical difference between the use of SNR device in the mathematics study unit compared to when the device is not used. That is, the SNR device increased the performance of the learners in mathematics based on the number of incorrect answers produced by learners during mathematics tests.

Based on the p-value level of significance, the alternative hypothesis is accepted and the null hypothesis is rejected.

Testing hypothesis 3

To test whether the use of the SNR device in mathematics increased or decreased learners' on-task behaviour, the third hypotheses were formulated: alternative hypothesis [H_1] and the null hypothesis [H_0] (see, Section 1.9.3).

- H_1: The use of the SNR device during a mathematics lesson increases learners' on-task behaviour.
- H_0: The use of the SNR device during a mathematics lesson does not increase learners' on-task behaviour.

ANOVA was used to test the assumptions. In addition, ANOVA was used to test the relationship between learners' number of 'No' answer or attempt to the question for tests that were written in different learning environment. First, when the SNR device was used in the classroom with the noise level range of 50 to 60 dBA. Thereafter, when the SNR device was not used in the classroom, with the noise level ranging from 70 – 80 dBA.

The study investigated whether the use of SNR device during classroom tests increased learners' on-task behaviour or not. The analysis focused on the number of times that learners failed to provide an answer to a question and the number of times that learners failed to attempt to answer particular questions in the algebra, basic and mental mathematics, and Euclidean geometry tests across the six schools. The following ANOVA table shows the results:

Table 5.6: ANOVA Test: Number of no answers or attempts

		Sum of Squares	Df	Mean Square	F	P-value	Group Mean
Between groups		92.010	2	46.005	1784.994	0.000	
Within groups		2.500	97	.026			
Group	With SNR						59
	No SNR						75
Total		94.510	99				

Since the p-value (0.000) was less than 0.05 level of significance, the results show that there is statistical difference between the use of SNR device in the mathematics achievement tests compared to when the device is not used. That is, the SNR device reduced the number of times that the learners in mathematics failed to attempt to answer questions during mathematics tests.

Based on the p-value level of significance, the alternative hypothesis is accepted and the null hypothesis is rejected.

Testing the main hypothesis:

To guide the research methodology the study, the main hypotheses were formulated: alternative hypothesis [H_1] and the null hypothesis [H_0] (see, Section 1.9.4).

- H_1: The use of the SNR device during a mathematics lesson increases learners' performance in mathematics.
- H_0: The use of the SNR device during a mathematics lesson does not increase learners' performance in mathematics.

The study investigated whether the use of SNR device during classroom tests improved the performance of the learners with regards to the number of correct answers, incorrect answers and no attempts produced in the algebra, basic and mental mathematics, and Euclidean geometry tests across six schools.

ANOVA was used to simultaneously test the relationship between learners' number of correct answers, incorrect answers and no attempts made by the in algebra, basic and mental mathematics and Euclidean geometry tests that were written in different learning environment. First, when the SNR device was used in the classroom with a noise level that ranged from 50 to 60 dBA. Thereafter, when the SNR device was not used in the classroom, the noise level was ranging from 70 to 80 dBA.

The study simultaneously computed the results used for hypothesis 1, 2 and 3, and determined whether it resulted in improving Grade 10 learners' performance in mathematics if ANOVA was applied simultaneously. The following ANOVA table shows the results.

Table 5.7: ANOVA Test: Correct and incorrect answers and no answers or attempt

	Sum of Squares	Df	Mean Square	F	P-value
Between groups	47.296	2	23.648	195.982	0.000
Within groups	11.704	97	.121		
Total	59.000	99			

The results show that there is statistical difference between the use of SNR and when the device control is not used since the p-value (0.000) is less than the level of significance 0.05. These findings express a significant increase in learners' performance in mathematics when the device control is used.

Based on the p-value level of significance, the alternative hypothesis is accepted and the null hypothesis is rejected.

5.5. SUMMARY

This chapter presented data related to the noise level in six Grade 10 mathematics classrooms that participated in the study. The proposed acceptable noise level for each phase of a mathematics lesson was also presented. Data related to mathematics teachers' perceptions on classroom noise, and how noise affected their teaching of mathematics were presented. Furthermore, data related to mathematics errors made by 205 learners in different topics of mathematics was presented. Data collected when the SNR device were used in the classroom with e noise level range of 50 to 60 dBA was

compared with data collected when the SNR device was not used in the classroom, with the noise level ranging from 70 to 80 dBA.

The ANOVA tests were applied to the number of errors that learners made in mathematics to tests and the results were used to test the hypotheses of the research questions.

CHAPTER SIX
DISCUSSION OF RESULTS, CONCLUSSION AND RECOMMENDATIONS

6.1 INTRODUCTION

The aim of the study was to develop a technological device (see, Chapter 3). The device was developed and was capable to send appropriate signal to the learners indicating the appropriate noise level in the classroom for the different phases of the mathematics lesson (see, Section 5.2). Throughout the report in this study, the device is referred to as the SNR device (see, Section 1.10.1).

The aim of using the SNR device in the current study was to improve learners' performance in mathematics by mitigating factors related to excessive classroom noise level as it emerged from the literature that noise contributes to learners' poor performance in mathematics (see, Section 1.5). In this study, the contributing factors to learners' poor performance in mathematics related to excessive classroom noise level were identified learners' inappropriate behaviour, lack of motivation to engage in learning, increase of ECL, and the loss of the teaching and learning time.

In the current study, each of the five factors was allocated to a sub-research question. (see, Section 1.8.2). In addition, out of five sub-research questions, three of them were tested by means of hypothesis (see, Sections 1.9 & 5.4.3.7).

The discussion of the data related to the sub-research questions and the hypotheses of the study is linked to the process of finding the answer to the main research question (see, Section 1.8.1), namely,

> *Does the use of a SNR device to control learners' undesirable noise in the classrooms increase their performance in mathematics?*

The discussion of the results to answer the main research question is also facilitated by literature review in Chapter Two, the conceptual framework (Section 2.7) and the research findings in Chapter Five. The discussion is followed by the conclusion, recommendations, limitations of the study, and future research study that may be conducted to broaden the use of the SNR device in other fields.

6.2 SUMMARY OF THE STUDY

The study aimed to mitigate the negative effects of learners' inappropriate noise level and the associated variable in mathematics classroom using the SNR device that aimed to assist in improving their performance in mathematics (Section 1.2). Data related to classroom noise level were collected in six schools for the duration of three years, with each successive year validating the findings of the previous year. The first year focused on collecting data related to the classroom noise level and assembling the SNR device. The second year was used as pilot study and focused on the validation of the SNR device (see, Sections 5.3 & 5.3.1 & Table 5.1). In the pilot study, data were collected from a group of Grade 10 learners (n=99) seeking to determine numbers and types of mathematics errors that the learners made in three type of tests administered to them in the classroom. This was controlled by SNR device with the noise level range of 50 to 60 dBA and the classroom without the SNR device with the noise level ranging from 70 to 80 dBA.

Data on teachers' general perceptions of classroom noise in their teaching were collected from three Grade 10 mathematics teachers using questionnaires (see, Sections 4.4.1, 5.3.2, 5.4.1;
Table 5.2 & 5.4; Appendix D). Lesson observations aimed in documenting classroom noise level and learners' inappropriate behaviour in the classroom were also conducted in the second year (see, Section 4.5.2). The third year was used as the main study and focused on the validation of the findings of the second year. The main study was carried out with another group of Grade 10 learners (n=106) who were doing mathematics, and three Grade 10 mathematics teachers (Section 5.4). Data collection in the main study followed a similar pattern of the pilot study, the only added feature was learners' post-test questionnaire. The total participants in the study were Grade 10 learners (n=205) and their

Grade 10 mathematics teachers (n=6). The study used the intervention research design (Section 2.8 & Table 2.7) and followed a mixed methods approach (Section 4.3 & Figure 4.1). Table 6.1 summarises the collection of data and its analysis.

Table 6.1: Summary of data collection and data analysis procedures for the study

Type of research question	Source of data	Section of the report in which it is analysed
Main (Section 1.8.1)	• Mathematics tests	• Section 5.3.4 & Section 5.4.3.6
	• Classroom noise level data	• Section 5.3.3 & Section 5.4.2
Sub-research question 1 (Section 1.8.2)	• Classroom noise level data	• Section 5.3.3 & Section 5.4.2
Sub-research question 2 (Section 1.8.2)	• Learners' post-test questionnaire	Section5.4.3.4.4 5.4.3.4
	• Teacher questionnaire	• Section 5.3.2 & Section 5.4.1
Sub-research question 3 (Section 1.8.2)	• Lesson observation sheet	• Section 5.3.3 & Section 5.4.2
Sub-research question 4 (Section 1.8.2)	• Mathematics tests	• Section 5.3.4 & Section 5.4.3.6
	• Classroom noise level data	• Section 5.3.3 & Section 5.4.2
Sub-research question 5 (Section 1.8.2)	• Mathematics tests	• Section 5.3.4 & Section 5.4.3.6
	• Classroom noise level data	• Section 5.3.3 & Section 5.4.2
Sub-research question 6 (Section 1.8.2)	• Mathematics tests • Classroom noise level data	• Section 5.4.3.5 & Section 5.4.3.6 Section 5.4.3.7

The following section discusses the results.

6.3 DISCUSSION OF RESULTS

6.3.1 Objectives of the study

Study objective 1 (Section 1.6.1): In terms of this objective, in identifying the standard sequencing and pacing of different lesson activities during mathematics instruction time, a number of mathematics lesson observations were conducted during the preliminary stage of data collection (see, Section 5.2). The lesson observation instruction guidelines were designed to capture teachers' pacing and the timing of different sections of a mathematics lesson (see, Sections 3.2 & 4.4.4). Therefore, this objective was accomplished.

Study objective 2 (Section 1.6.2): In terms of the objective that was set to identify and measure the levels of learners' noise during mathematics lessons in selected schools, the classroom noise level was constantly recorded using the SLM when the researcher visited the classrooms during Grade 10 mathematics lessons (see, Section 4.5.2.2). During the preliminary and the pilot phase of data collection, the noise level of learners was constantly recorded with the SLM and the data were captured on the lesson observation instruction guidelines (see, Sections 4.4.4 & 5.3.3). In the main study, data were recorded by the SLM, with a computer and noise level software (see, Figure 5.17; Figure 5.18 &

Figure ***5.19***). Therefore, this objective of the study was accomplished.

Study objective 3 (Section 1.6.3): In terms of this objective, which had been set to incorporate into the SNR device the appropriate noise levels, the timing and different activities for mathematics lessons. Chapter Three of this study has provided a detailed discussion on how the built-in feature of the SNR devise was utilized to control learners' noise at different stages of Grade 10 mathematics lesson. The data presented in Section 5.2 supports this study objective. Therefore, this objective of the study was accomplished.

Study objective 4 (Section 1.6.4): In terms of this objective, which had been set up to use the SNR to monitor classroom noise levels during mathematics lessons while observing its influence on learners' performance in different topics in mathematics. The SNR device was used in all six schools during the pilot phase and during the main phase of data collection to influence learners to reduce classroom noise levels (see, Sections 5.3.3 & 5.4.2). In terms of using the SNR device and monitoring its influence on learners' performance in different topics of Grade 10 mathematics, different mathematics achievement tests were administered to the learners. Learners wrote three type of tests based on the algebraic concepts, Euclidean geometry and basic mental calculations. The tests were administered to the learners in the classroom that was controlled using the SNR device with the noise level range of 50 to 60 dBA and the classroom that was without the SNR device with the noise level ranging from 70 to 80 dBA. The data were analysed using mathematics errors analysis (see, Section 4.7.5). Therefore, this study objective was also accomplished.

6.3.2 Discussion of results relating to the research questions of the study

6.3.2.1 Sub- research question 1

The sub-research question 1 is posed in Section 1.8.1 and is answered using the classroom noise level data collected during the pilot and the main study phase. In School A the average noise level in the classroom in which the SNR device was incorporated was 69,8 dBA. The average noise level in a classroom that was without the SNR device was

71,8 dBA (see, Figure 5.6). The classroom without the SNR device experienced an increase of 3% of the noise level (see, Section 5.3.3.1).

In School B, the average noise level in the classroom with the SNR device was 52 dBA while the average noise level in the classroom without the SNR device was 57 dBA (see, Figure 5.7). The classroom without the SNR device experienced an increase of 10% of the noise level (see, Section 5.3.3.2).

In School C, the average noise level in the classroom with the SNR device was 55,6 dBA while the average noise level in the classroom without the SNR device was 61,9 dBA (see Figure 5.8). The classroom without the SNR device experienced an increase of 11% of the noise level (see, Section 5.3.3.2).

In School D, the average noise level with the SNR device was 61,1 dBA while the average noise level without the SNR device was 64 dBA (see, Figure 5.17). This shows that without the SNR device, the noise increased by 5% (see, Section 5.4.2.1).

In School E, the average noise level without the SNR device was 70,5 dBA while the average noise level with the SNR device was 69,6 dBA (see, Figure 5.18). This shows that with the SNR device the noise decreased about 1% (see, Section 5.4.2.2).

In School F, the average without the SNR device was 63,5 dBA while the average with the SNR device on was 62,3 dBA (see,

Figure ***5.19***). This shows that with the SNR device the noise decreased about 2% (see, Section 5.4.2.3).

Across the six schools, the mean average of the noise level in the classroom without the SNR device was 64,8 dBA while the mean average of the noise level in the classroom with the SNR device was 61,7 dBA. This shows an overall 4,8% reduction of the classroom noise level when the SNR devices was used. The 4,8% reduction of should be understood in the context of noise and sound measurements: *A drop of 3 dBA means that the noise level is cut to half its previous level* (Milne, 1979: 58).

As discussed in Section 2.2, sound pressure in kPa is logarithmically converted into dB. Milne (1979: 58) postulates that the implication of a logarithmic conversion of sound pressure kPa into dBA is that a small change in decibel value can cause a tremendous change in intensity of noise. Mulholland and Attenborough (1981) used a day-to-day example show how to interpret the percentage increase in the noise level.

Mulholland and Attenborough (1981: 15) explain that even though a single motorcycle may create 100 dBA at a kerbside, it does not mean that two motorcycles will create 200 dBA. The result of adding two identical sound levels together suggests an increase of 3 dBA, meaning that two motorcycles will generate 103 dBA. Based on this understanding of how the noise level in dBA increases when the sound power is doubled, it is logically correct to state that the SNR device reduced the noise level to more than half. In terms of the number of learners in the classroom, if for example 20 learners were making noise, the SNR device would influence more than a half of 20 learners to be quiet.

Based on the observation of learners' behaviour and the recording of the noise level in mathematics lessons, the researcher does agree that "a drop of 3 dBA means that the noise level is cut to half its previous level" (Milne 1979: 58). For example, in the lesson observation and recording of noise level in School A, the researcher noted that in a class of 30 learners, only ten out of 30 learners seemed to be fully engaged. At least eight learners were disturbing others at any time. At some point, one learner was singing while another learner threw an eraser at a fellow learner. When the SNR device was used, there

was notable classroom orderliness. Nevertheless, the percentage decrease of noise level was just 3%.

6.3.2.2 Sub-research question 2

The sub-research question 2 is posed in Section 1.8.2, and is answered by data collected using teachers' questionnaires and learners' post-test questionnaire.

The mean responses of teachers' questionnaire in the pilot study and the main study show the extent to which teachers are affected by noise in their practice (see,

Table 5.2 & Table 5.4). One of the questions on the in the questionnaire was about the teaching time of Grade 10 mathematics class. The following question was posed: *During the lesson, how often do you feel that time has been lost because of learners' noise in your Grade 10 mathematics class?* In the pilot study, the teachers felt or perceived that it happened in rare occasions or about 43% of time (see, Section 5.3.2). In the main study, the teachers felt or perceived that it happened very frequently or about 67% of time (see, Section 5.4.1). By combining teachers' responses in the pilot study and the main study, the mean average response shows that overall, the teachers felt or perceived that it happened occasionally or about 54% of the time (see, Section 4.7.2, Table 4.11*:* & Appendix I).

The responses from the learners' post-test questionnaire revealed the extent to which the SNR device was instrumental in assisting the management of learning time. After learners finished writing different mathematics achievement tests in a classroom environment controlled by the SNR device, they wrote similar tests, given the same time in a noisy classroom environment without the SNR device. In the algebra test, 53 out of 161 responses indicated that learners needed more time, that is, about 33% of the responses (see, Figure 5.29).

In mental and basic mathematics calculations, 19 out of 142 learners indicated that they needed more time, that is, about 13% of the responses (see Figure 5.30). In the Euclidean geometry test, 53 out of 153 responses indicated that they needed more time, meaning an about 35% of the responses (see, Figure 5.31). When the responses were combined, 125 out of 421 learners' responses, meaning an about 29.7% of all responses indicated

that they needed more time (see, Figure 5.32). It is noteworthy to see that out of all options given to the learners in the post-test questionnaire, the time factor was the most contributing out of all other options. Even though the data were collected during the test, these findings show that the SNR device does increase learning time during mathematics lessons.

As discussed in Section 2.5.2, this study supports the findings of the study done by physician Julia Barnett in the 1920's about the effects of noise on teaching time (Hendy, 2013). This study highlights that the effects of noise on the teaching and learning time particularly in mathematics is still as relevant as when it was studied 100 years ago.

6.3.2.3 Sub-research question 3

The sub-research question 3 is posed in Section 1.8.2, and is answered using data collected by means of teacher questionnaire and classroom observations.

The mean responses of the teachers' questionnaire in the pilot study and the main study show the extent to which teachers are affected by noise in their practice (see,
Table 5.2 & Table 5.3). Two questions on the in the questionnaire was about learners' inappropriate behaviour of Grade 10 mathematics class. This question was posed: *How often does learners' noise in your Grade 10 mathematics class turn out to be disruptive behaviour?* and another question was *How often does learners' noise in your Grade 10 mathematics class affect fellow learners' concentration?* The combined teachers' responses of each of the two questions using the mean average response shows that in overall, the teachers feel or perceived that it happens occasionally or about 53% of time (see, Appendix I, Section 4.7.2 & Table 4.4).

In the classroom observations, the researcher noted that some Grade 10 mathematics classes who participated in this study behaved reasonably well. Grade 10 mathematics learners in Schools B, D and F behaved reasonably well (see, Sections 5.3.3.2, 5.4.2.1 & 5.4.3.3). In the case of School B, D and F, there was little difference in terms of learners' inappropriate behaviour in the classroom, regardless of whether the SNR device was used or not. By observing learners' inappropriate behaviour in School F, the lesson observation

was an eye opener to the researcher, as the lesson became the example of how the SNR can be used for cooperative learning (see, Section 5.4.2.3).
During the observations of the Grade 10 mathematics lessons, the researcher noted some level of learners' inappropriate behaviour in Schools A, C and E (see, Sections 5.3.3.1, 5.3.3.3 & 5.4.3.2). In the case of mathematics class of the Schools A, C and E, there was an improvement in terms of learners' inappropriate behaviour in the classroom when the SNR device was used.

In School A without the SNR device, at least 20 learners were not engaged in the lesson. The majority were simply daydreaming or idling, at least eight learners were talking to one another at any time of the lesson. At one time, one learner was singing, and one learner threw an eraser at his friend instead of passing along. In School A with the SNR device, there was no inappropriate behaviour from learners (see, Section 5.3.3.1).

In School C, without the SNR device, at least eight learners seemed to be idling. At a certain time, the researcher observed a learner who very much engaged while at the same time was chewing and unconsciously popping chewing gum. During the lesson, learners shouted out the answers. In School C with the SNR device, there was order and learners were actively listening and cooperating with one another (see, Section 5.3.3.3).

In School E without the SNR device, at least four learners were speaking to each other and were disengaged. Three learners called out for the answers to their friends. At some time during the lesson, a learner coughed out to clear the throat, and fellow learners reacted with an amusement of noise. In School E with the SNR device, there was order in the classroom as learners paid attention while a fellow learner explained her calculation in the front of the class, on the black board (see, Section 5.4.2.3).

The sub-research question *What types of learners' inappropriate classroom behaviour may the SNR device reduce?* was subject to learners' behaviour in the classroom. In the classrooms where learners behaved reasonably well, there was little difference in terms of learners' inappropriate behaviour regardless of whether the SNR device was present

or not. In the classroom with a level of learners' inappropriate behaviour, learners became cognisant of the presence of the SNR device and cooperated in the learning. The types of learners' inappropriate classroom behaviour that the SNR device reduced are those that included elements of noise, like talkativeness, shouting out the answer, or simply having friendly discussions with their peers.

6.3.2.4 Sub-research question 4

The sub-research question 4 is posed in Section 1.8.2, and is answered from the data collected by means of learners' mathematics tests, analysed by means of mathematics errors analysis and testing hypothesis 1.

In a noise classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners scored a total of 599 correct answers in algebra for across all six schools. In the classroom environment without the SNR device with the noise level of 70 to 80 dBA, learners scored 345 correct answers. This accounts for a 42% increase in accuracy (see, Section 5.4.3.5.1 & Figure 5.33).

In the basic mental mathematics calculations, the combined results of correct answers in a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA was a total of 928 correct answers.

In the classroom environment without the SNR device with the noise level of 70 to 80 dBA, learners scored 688 correct answers. This accounts for an increase in accuracy of 26% (see, Section 5.4.3.5.2 & Figure 5.34). In the Euclidean geometry test, the combined results of correct answers in a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, was a total of 1073 correct answers. In the classroom environment without the SNR device with a noise level of 70 to 80 dBA, learners scored 973 correct answers. This accounts for an increase in accuracy of 9% (see, Section 5.4.3.5.3 & Figure 5.35). For all combined results, regardless of the topics of mathematics, in a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 2600 correct answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored a total of 2006

correct answers. This indicates that the increases of the noise in the classroom decreased the correct answers by 23% (see, Section 5.4.3.6 & Figure 5.36).

Furthermore, by using the hypothesis testing the alternative hypothesis was adopted (see, Section 5.4.3.7 & Table 5.5). The SNR device therefore does increase learners' accuracy in mathematics.

6.3.2.5 Sub-research question 5

The sub-research question 5 is posed in Section 1.8.2, and is answered through data collected by means of learners' mathematics achievement tests which was analysed by means of mathematics errors analysis and the testing of hypothesis 2.

In a noisy classroom environment controlled by the SNR device with a noise level ranging from 50 to 60 dBA, learners scored a total of 713 incorrect answers in algebra across all six schools. In the classroom environment without the SNR device with the noise level of 70 to 80 dBA, learners scored 833 incorrect answers. This accounts for an increase of the number of incorrect answers by 17% (see, Section 5.4.3.5.1 & Figure 5.33). In the basic mental mathematics calculations, the combined results of incorrect answers in a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, produced a total of 444 incorrect answers. In the classroom environment without the SNR device, with the noise level of 70 to 80 dBA, learners scored 586 incorrect answers. This accounts for an increase of incorrect answers by 32% (see, Section 5.4.3.5.2& Figure 5.34). In the Euclidean geometry test, the combined results of incorrect answers in a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, produced a total of 714 incorrect answers. In the classroom environment without the SNR device with the noise level of 70 to 80 dBA, learners scored 754 incorrect answers. This accounts for an increase of incorrect answers by 6% (see, Section 5.4.3.5.3 & Figure 5.35). For all combined results, regardless of the topics of mathematics, in a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners produced a total of 1871 incorrect answers. In the classroom environment with a noise level of 70 to 80 dBA, learners scored

a total of 2173 incorrect answers. This indicates that the increases of the noise in the classroom decreased the incorrect answers by 16% (see, Section 5.4.3.6 & Figure 5.36).

In order to understand whether the learners' mistakes related to the extra cognitive load that the noise level exerted on their working memory, the post-test questionnaire was given to learners. About 22.3% of all responses from the learners indicated that it was confusing to work in a noisy environment of 70 to 80 dBA compared to a noise environment of 50 to 60 dBA, when the SNR device was used (see, Section 5.4.3.4.4).

Furthermore, by using the ANOVA to test the second hypothesis, the alternative hypothesis was adopted (see, Section 5.4.3.7 & Table 5.5). The use of the SNR device during a mathematics lesson reduced learners' ECL in mathematics. An excessive classroom noise level without the SNR device does add extra burdens on the learners' working memory and therefore increases learners' incorrect answers in mathematics.

6.3.2.6 Sub-research question 6

The sub-research question 6 is posed in Section 1.8.2, and is answered using data collected by means of learners' mathematics achievement tests analysed by means of mathematics errors analysis and testing hypothesis 3.

In a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners did not attempt to answer a total of 516 answers in algebra across all six schools. In the classroom environment without the SNR device with a noise level of 70 to 80 dBA, learners did not attempt to answer a total of 644 answers. This accounts for an increase of not attempting to answer questions by 36% (see, Section 5.4.3.5.1 & Figure 5.33). In the basic in mental mathematics calculations, the combined results of learners failing to attempt to answer questions. In a noisy classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners made no attempt to produce a total of 48 answers. In the classroom environment without the SNR device with the noise level of 70 to 80 dBA, learners did not attempt to answer a total of 132 answers. This accounts for an increase of not attempting to answer questions by 132% (see, Section 5.4.3.5.2 & Figure 5.34). In the Euclidean geometry test, the combined results of learners not attempting to answer questions in a noisy classroom

environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA was a total of 437 questions. In the classroom environment without the SNR device with the noise level of 70 to 80 dBA, learners did not attempt to answer a total of 492 answers. This accounts for an increase of not attempting to answer questions by 13 % (see, Section 5.4.3.5.3 & Figure 5.35).

For all combined results, regardless of the topics of mathematics, in a classroom environment controlled by the SNR device with the noise level ranging from 50 to 60 dBA, learners did not attempt to answer a total of 1871 questions. In the classroom environment with a noise level of 70 to 80 dBA, learners did not attempt to answer a total of 2173 questions. This indicates an increase of the noise level in the classroom. This indicates that by controlling the noise, learners are encouraged to attempt many questions by 27% (see, Section 5.4.3.6 & Figure 5.36). Furthermore, by using the ANOVA to test the third hypothesis, the alternative hypothesis was adopted (see, Section 5.4.3.7 & Table 5.6). Therefore, the use of the SNR device during a mathematics lesson increases learners' on-task behaviour.

6.3.2.7 The main research of the study

The main research question was posed in Section 1.8.1. The main research question is connected to all six sub-research questions (see, Section 1.8.2) and the study objectives (see, Section 1.6). As discussed in Section 1.1 learners' performance in mathematics may be linked to many factors, which may also be linked to learners' noise in the classroom (Robarts, 2014; Salum & Shahrill, 2014; Zhang, 2015).

Using the conceptual framework of the study in Table 2.3, each factor related to learners' noise in the classroom and linked to poor learners' performance in mathematics has been addressed throughout the study. The SNR device was used to address the issue of learners' inappropriate behaviour in the classroom. The empirical data show that whenever the SNR device was used, learners' inappropriate behaviour in the classroom was reduced and there was a sense of order during the lesson (see, Sections 5.3.3.1 & 6.3.2.3).

The SNR device was used to address the issue of learners' noise level in the classroom. The empirical data show that whenever the SNR device was used learners' noise level in the classroom subsided (see, Sections 5.3.3, 5.4.2 & 6.3.2.1).

The SNR device was used to address the issue of learners' motivation to to determine the extent to which the learners engage in on-task behaviour during mathematics lessons. The empirical data show that whenever the SNR was used during mathematics achievement tests, learners attempted many questions than when SNR was not used (see, Section 5.4.3.6 & Figure 5.36).

The SNR device was used to address the issue of teaching and learning time. The empirical data show that whenever the SNR was not used during mathematics tests, learners complained about not having enough time to complete their tests (see, Section 5.4.3.4.4 & Figure 5.32).

The SNR device was used to address the issue of learners' ECL. The empirical data show that whenever the SNR was not used during mathematics tests, learners made many mistakes compare to when the SNR device was used (see, Section 5.4.3.6 & Figure 5.36). In understanding whether the mistakes were related to the extra cognitive load that the noise level exerts on learners' working memory, the post-test questionnaire was given to learners. About 22.3% of all responses from the learners indicated that it was confusing to work in a noisy environment of 70 to 80 dBA compared to the noise environment of 50 to 60 dBA when the SNR device was used (see, Section 5.4.3.4.4 & Figure 5.32).

Factors related to the effects of classroom noise on the well-being of teacher and learners were also considered. The following question was posed: *How often do you feel irritated because of learners' noise in your Grade 10 mathematics class?* The combining teachers' responses in the pilot study and the main study show that overall, the teachers felt that it happened occasionally or about 47% of the time (see, Section 4.7.2, Table 4.11*:* & Appendix I).

The effects on the SNR device on learners' well-being have been performed using the post-test questionnaire. Even though the noise of the music of popular South African musicians were used when learners were writing tests, about 60,3% of learners'

responses still show elements of their well-being being affected. In contrast, about 29.7% indicated that they needed more time while about 22.3% indicated that it was confusing and about 8.3% indicated they did not feel happy.

The remaining 39,7% learners did not seem to worry about the noise level, about 23.3% said that they felt happy, and about 16.4% indicated that they felt normal (see, Section 5.4.3.4.4 & Figure 5.32). This could have been caused by the fact that the noise that was produced for the current study for ethical consideration was music (songs). The rational of playing the music instead of creating other kind of noise in the classroom was to comply with research ethics (Section 4.9). In addition, the type of music played was helpful in eliminating extraneous variables that could have affected the internal validity of the study such as tiredness and stress (Section 4.6.3.3). While the research used the normal noise sources as in a normal classroom, the responses of learners with tolerance to noise would have changed their perceptions. The researcher analysed the scripts of learners who responded that they felt happy and normal to see whether they performed better in the tests. The data show that they performed poorly in the tests when the SNR device was not used.

Finally, the main assumption of the study (*the use of the SNR device during a mathematics lesson enhances learners' performance in mathematics*) was tested using the two-way ANOVA. The total results from the mathematics tests, from all six schools, across three topics used in mathematics achievement tests (the algebra, Euclidean geometry and basic mental calculations tests) in terms of the number of correct answers, incorrect answers and no answer was tested using two-way ANOVA test.

Based on the p-value level of significance [the p-value (0.000) is less than the level of significance 0.05], the alternative hypothesis is accepted and the null hypothesis is rejected. Therefore, based on the ANOVA tests and the findings mentioned in this section, the researcher is justified to state that the SNR device improves learners' performance in mathematics (see, Section 5.4.3.7 & Table 5.7).

6.4 CONCLUSION

The current study developed a SNR device that can be used to mitigate Grade 10 learners' poor performance in mathematics. The study provides evidence that a host of variables is associated with poor performance in mathematics. A number of the variables associated with poor performance in mathematics include elements of learners' classroom noise: learners' inappropriate behaviour, learners' ECL, learners' motivation to engage in the lesson, and the time of teaching and learning.

The study demonstrated that the SNR device is a technological model that can be used to control learners' classroom noise and the associated negative variables, and therefore improve Grade 10 learners' performance in mathematics.

6.5 LIMITATIONS OF THE STUDY

The study encountered some limitations in the pilot study phase, and these limitations were resolved during the main phase of the study (see, Section 4.5.2). One significant limitation of the study related to the implication of studying the trends of Grade 10 mathematics class for one year only after which the group would move on to the next Grade. At one instance, School A did not participate in the basic and mental calculations tests (see, Table 4.2*:*). This was caused by the fact that by the time the test was to be administered, teachers at the school were not teaching and permission by the GDE was about to expire the following week. This meant that the test could not be given to the same learners the following year as there would another group of learners.

6.6 RECOMMENDATIONS

This study was both a development and an evaluation study whose aim was to design a SNR technological device and assess its potential in monitoring extraneous noise in mathematics classrooms, with a view to increasing efficiency of teacher control of classroom learning environments.

The study has proved that an environment conducive to learning is vital in order to improve learners' performance in mathematics. Hence, the following recommendation is made to educational policy makers in mathematics education:

- Educational policy makers in mathematics education need to invest their effort to implement the use of classroom assistive technology such as the SNR device to assist mathematics teachers in their classroom management, to manage the learners' noise level and other variables associated with excessive classroom level, with a view to bring about an ideal mathematics classroom learning environment.

The study has further proved that by controlling learners' classroom noise level, other variables causing poor performance in mathematics namely learners' disruptive behaviour, learners and teachers' wellbeing, learners' lack of motivation to learn, the loss of teaching and learning time, and learners' extraneous cognitive load are simultaneously controlled during mathematics lessons. Hence, the following recommendation is made to mathematics teachers:

- Mathematics teachers need to embrace the use the SNR device as an assistive technology in their mathematics classroom management style. Technology in the classroom needs to include aspects to improve the classroom noise level learning atmosphere for mathematics. There are numerous technological advancements to improve learning: the use of a smart board, smart phones, tablets, television educational channels and blended learning via a learning website (Mhlanga, 2018). However, the learning physical atmosphere inside the classroom is stagnant to move ahead with the technology of time. For example, teachers still stick to the conventional way of using their voices, and keep repeating information to inform learners to stop making noise in the classroom. In other instances, mathematics teachers stop their lesson for a moment and wait for the classroom noise to become ideal for learning. This wastes time for learning (OECD, 2004, p.214-2015).

The study also found that whenever learners were orally asked to perform simple basics mathematics calculations in uncontrolled noise level classroom environment, the learners performed poorly. Learners attributed their poor results in the basics mathematics calculations to the fact that they could not clearly hear the questions. Therefore, the following recommendation is also made to a community of mathematics teachers:

- A community of mathematics teachers that may be using oral mathematics type of assessments as a method of grading the learners, need to ensure that they take into consideration the classroom noise level variable, and use assistive technologies such as the SNR device to control the noise level whenever it is possible.

Furthermore, data from the achievement mathematics tests collected from the learners proved that in learners' accuracy in responding to algebraic tasks, Euclidean geometry and basic and mental calculations increased by 23%, and their incorrect answers decreased by 16% in a classroom noise environment of 50 to 60 dBA compare to a classroom environment whereby the music was played, and noise level was in range of 70 to 80 dBA. Therefore, the following recommendation is made to assist the learners and their parents or guardians who may be assisting their children to study mathematics or to do mathematics homework:

- Learners need to be cautioned about the negative effects of noise; including the negative effects of music on their performance in the subject of mathematics. This caution is timely important because of the prevalence of mobile technological devices for music. In the technology era with smart phones, learners on their personal level may be inclined to study mathematics while listening music using their earphones.

6.7 FURTHER RELATED RESEARCH

Mandela (2004) said "after climbing a great hill, one only finds that there are many more hills to climb" (Mandela, 2004 p.385). These words reflect the sentiments of the researcher in this study. The researcher sees a need to conduct at least three more studies to expand on the findings of this current study. The studies may focus on:

- Implementation of the use of the SNR device in the larger mathematics teacher-community
- Improving the technological features of the SNR device in line with the fourth industrial revolution, and
- Expanding the use of SNR device to settings beyond mathematics classroom and beyond the educational settings.

Firstly, the study developed a SNR device with a view to mitigate learners' poor performance in Grade 10 mathematics classrooms. The SNR device was used in a series of single experimental design to evaluate its capability to control extraneous noise in mathematics classrooms. Learners wrote three types of achievement assessments in a classroom environment controlled by SNR device with the noise level range of 50 to 60 dBA and the classroom without the SNR device with the noise level ranging from 70 to 80 dBA. Also, data related to classroom noise level was firstly recorded using the sound level meter in a classroom environment without the SNR device and thereafter the SNR device was fitted in the classroom. Data was mostly collected from the learners.

The researcher recommends that an implementation study be conducted on large community of mathematics teachers using the SNR device in their classrooms. The study would position the use of the SNR device in mathematics lessons in broader conceptual framework, namely in the area of assistive technologies for teaching and learning. Since the technological features of the SNR device would be operated by mathematics teachers, it would be appropriate to train the teachers how to use it. Thereafter, it would be beneficial to allow a broader community of mathematics teachers to use the SNR device in their natural teaching classroom without interference from the researcher.

The current study incorporated the best researched mathematics lesson format in the SNR device (see Table 3.1). However, in the proposed implementation study, the researcher sees a need to give the mathematics teachers the freedom of choice on the lesson format that they would prefer to use in their lessons. Therefore, the researcher recommends that in the implementation study the SNR device may include at least three lesson format programmes so that teachers may decide the format that suits their preferences.

Secondly, the aim of the study was to develop and use the SNR device in improving the mathematics performance of Grade 10 learners by mitigating factors associated to the extraneous noise in the classroom. The study achieved its aim and objectives. However, during the different stages of the study; in the literature review, in the assembling of the SNR device and in the interaction with the participants in this study, it became evident that noise pollution does interferer with human health and their daily activities in settings that

are beyond mathematics classrooms. For instance, in an educational setting, the researcher encountered in school hallways, school libraries, school study rooms, boarding schools' dormitories and cafeterias the signages written "Keep quiet, examination in progress; quiet zone; respect, those studying around you; observe silence; keep the noise to a minimum; or silence please". Also, in the setting beyond the education environment, the researcher has noticed inside and surrounding hospitals' buildings and old age homes, the signages written "no hooting, quiet please healing in progress" signalling a silence zone. Therefore, the researcher proposes an undertaking of further series of empirical studies that use the technological features of the SNR devices with view of improving learning environment inside the classrooms of other learning subjects. In other learning subjects, the researcher would need to study the timing, the noise level of phases of learning subjects and incorporate them in the SNR device. Future empirical studies may also be needed to determine the efficacy of the SNR device in controlling noise in school hallways, school libraries, school study rooms, boarding schools' dormitories and cafeterias. In situations beyond the educational settings like controlling noise level in hospitals' buildings and old age home a number of studies may also be conducted to determine if other features of the SNR device are needed to be added or whether there may be a need to adjust the settings of the SNR device.

Finally, as mentioned by Hendy (2013), we are living in the 'noise amplified age' whereby the conquering engines and the rise of the machines of the first three industrial revolutions have consistently increased the level and rate of noise recurrence in the environment (Hendy, 2013). As the world moves ahead into the fourth industrial revolution, with advancement in robotics and artificial intelligence, it is logical to predict that some future technological advancement will increase the noise level in educational setting, particularly in the mathematical learning environment. Therefore, the researcher holds some expectations that more studies should be conducted to improve the functionalities of the SNR device to reach beyond a mathematics education setting.

The following possibilities may be investigated:

- Some artificial intelligence features may be added to the SNR device, and include voice recognition that specifically warn a specific individual learner who has exceeded the recommended classroom noise level.
- The SNR device may be in the future be included with a recording of the lesson feature. An upgrading of the SNR device with the ability to record a lesson may further assist the teacher and the school management team in charge of learners' behaviour to timeously respond to learners' inappropriate behaviour that may develop in the classroom. Furthermore, the recording feature of the SNR device may be used beyond the role of classroom management. For example, if a learner for some reason misses the lesson, the recordings of the lesson may be used to assist the learner to catch up.

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APPENDICES

APPENDIX A_1: ALGEBRA TEST: WITH EXCESSIVE CLASSROOM NOISE (70 – 80DBA)

Rubric Codes and marking guidelines

Description	Correct answer /Step	Incorrect answer /Step	No answer /Attempt
Code	1	2	3

1	Simplify:		
	$(x+1)-2x^2(x-1)^2$		
	$(x+1)-2x^2(x-1)(x-1)$	Multiply each term inside the brackets expanding and multiplying $(x-1)^2$	
	$(x+1)-2x^2(x^2-2x+1)$	Removing the brackets by multiplying the terms	
	$(x+1)-2x^4+4x^3-2x^2$	Accuracy of exponents, accuracy for signs(coefficient)	
	$-2x^4+4x^3-2x^2+x+1$	Rearranging polynomials from the highest exponent to the lowest exponent.	
2.1	Simplify.		
	$\left(x-\frac{1}{x}\right)^2$		
	$(x-\frac{1}{x})(x-\frac{1}{x})$	Expanding the brackets	
	$x^2-\frac{x}{x}-\frac{x}{x}+\frac{1}{x^2}$	Multiply each term correctly. $x^2;\frac{x}{x};\frac{1}{x^2}$.	
	$x^2-1-1+\frac{1}{x^2}$	Recognising that $\frac{x}{x}=1$	
	$x^2-2+\frac{1}{x^2}$	Final answer	
2.2	Evaluate $x^2+\frac{1}{x^2}$ if given that $(x-\frac{1}{x})=5$		
Recognising that	$\left(x-\frac{1}{x}\right)^2 = x^2-2+\frac{1}{x^2}=(5)^2$		(3)
Recognising that	$x^2+\frac{1}{x^2}=x^2-2+\frac{1}{x^2}+2=(5)^2+2$		

Final answer	$x^2 + \frac{1}{x^2} = 27$		(5)

APPENDIX A2: ALGEBRA TEST: WITH MODERATE CLASSROOM NOISE (50-60DBA)

Rubric codes and marking guidelines

Description	Correct answer /Step	Incorrect answer /Step	No answer /Attempt
Code	1	2	3

1. Simplify			
	$(m-m)(3m-2mn+4)$	Accuracy (writing as it appears on the question)	
	$3mn-2mn^2+4n-3m^2+2m^2n-4m$	Removing the brackets by multiplying the terms	
	$-3m^2-2mn^2+2m^2n-3mn+4n-4m$	Accuracy of exponents, accuracy for signs(coefficient) Rearranging polynomials from the highest exponent to the lowest exponent.	
2.1	Simplify.		
	$(m+\frac{1}{m})^2$		
	$(m+\frac{1}{m})(m+\frac{1}{m})$	Expanding the brackets	
	$m^2+\frac{m}{m}+\frac{m}{m}+\frac{1}{m^2}$	Multiply each term correctly. $m^2;\frac{m}{m};\frac{1}{m^2}$.	
	$m^2+1+1+\frac{1}{m^2}$	Recognising that $\frac{m}{m}=1$	
	$m^2+2+\frac{1}{m^2}$	Final answer	
2.2	Evaluate $m^2+\frac{1}{m^2}$ if given that $m+\frac{1}{m}=3$		
Recognising that	$(m+\frac{1}{m})^2 = m^2+2+\frac{1}{m^2} = (3)^2$		
Recognising that	$m^2+\frac{1}{m^2} = m^2+2+\frac{1}{m^2}-2 = (3)^2-2$		
Final answer	$m^2+\frac{1}{m^2}=7$		

APPENDIX A_3: LEARNERS' POST-TEST QUESTIONNAIRE

Instructions:

Use a tick (✓)below the correct word to indicate your experience during the Algebra test

In the algebra test with noise (music), I felt that:	I felt that it was confusing	I felt I needed more time	I felt happy	I felt normal	I did not feel happy	Other

APPENDIX B_1: MENTAL MATHS & BASIC CALCULATIONS TEST:

INSTRUCTIONS

1. Please follow the instructions as projected on the screen and answer all the questions on the answer sheet provided.
2. The questions will be displayed on the screen by means of the projector.
3. Write down the answer and work it out on the answer sheet provided.
4. You will be given 10 seconds to answer the question and thereafter the next slide with a question will come up.

Rubric Codes and marking guidelines

Description	Correct answer	Incorrect answer	No answer /Attempt
Code	1	2	3

With moderate classroom noise (50 – 60dBA)			**With excessive classroom noise (70 – 80 dBA)**	
No.	QUESTION	ANSWER	QUESTION	ANSWER
1	Write down the following phone numbers: 0826768126	082 676 8126	Write down the following phone numbers: 062 116 2157	062 116 2157
2.	What is the product of 7 and 9 (7 times 9)	63	What is the product of 6 and 9 (6 times 9)	54
3.	Write down the following values of pi: 3,141593	3,141593	Write down the following values of $\sqrt{5}$: 2,236068	2,236068
4.	How many cents are in R2?	200 cents	How many cents are in R1?	100
5	Arrange the following unit of measurements from the smallest to the biggest. Meter, kilometer, centimeter.	Centimeter, meter, kilometer,	Arrange the following unit of measurements from the smallest to the biggest. Liter, kiloliter, millilter.	Milliliter, Liter, kiloliter,
6	Find the value of $3x$ multiply by $3x$	$9x^2$	Find the value of 5y multiply by 5y	$25y^2$
7	Find the value of x divide by x	1	Find the value of y divide by y	1
8	Evaluate: 50% of 20	10	Evaluate: 50% of 10	5
9	Evaluate: ¾ of 100	75	Evaluate: A quarter of 100	25
10	What is the difference between – 20 and 12	32	What is the difference between – 10 and – 20	10

APPENDIX B_2: LEARNERS' POST-TEST QUESTIONNAIRE

Instructions:

Use a tick (✓)below the correct word to indicate your experience during the Basic & Mental mathematics test

In Basics and mental mathematics test with noise (Music), I felt that:	It was confusing	I needed more time	I felt happy	I felt normal	I did not feel Happy	Other

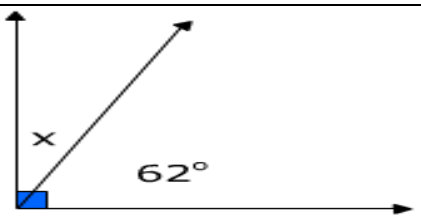
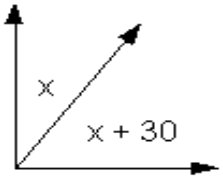
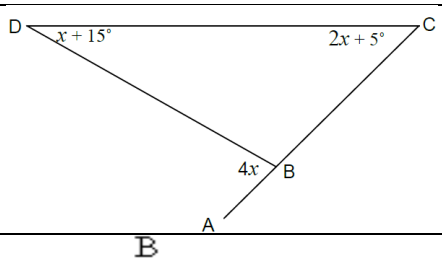
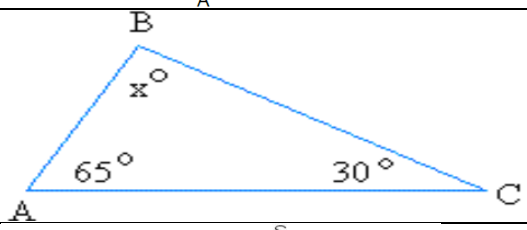
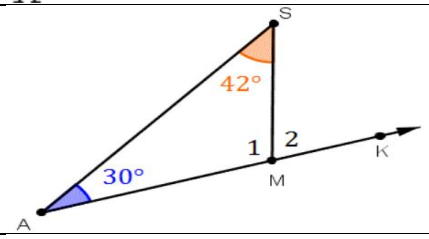
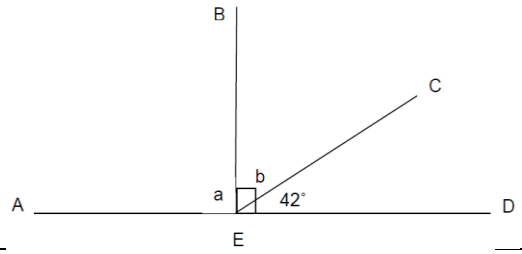
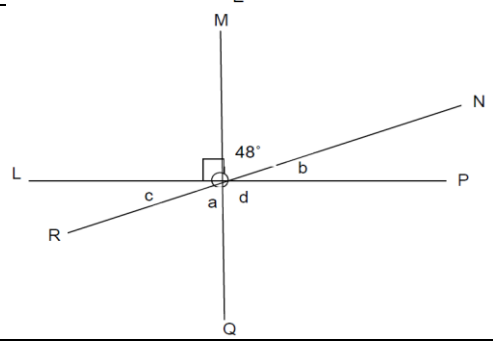
APPENDIX C_1: GEOMETRY TEST: WITH MODERATE CLASSROOM NOISE (50-60DBA)

INSTRUCTIONS

1. Please follow the instructions as projected on the screen and answer all the questions on the answer sheet provided.
2. The questions will be displayed on the screen by means of the projector.
3. Write down the answer and calculation on the answer sheet provided.
4. You will be given 60 seconds to answer the question and thereafter the next slide with a question will come up.

Rubric Codes and marking guidelines

Description	Correct answer	Correct Statement	Incorrect answer	Incorrect Statement	No answer /Attempt	No Statement
Code	1	2	3	4	5	6

Number		Statement(answer)	Reasons
1		$x + 62^o = 90^o$ $x = 90^o - 62^o$ $x = 28^o$	Compl. angle
2.		$x + x + 30^o = 90^o$ $2x = 90^o - 30^o$ $x = 60^o$	Compl. angle
3.		$x + 15^o + 2x + 5^o = 4x$ $3x + 20^o = 4x$ $-4x + 3x = -20^o$ $x = 20^o$	Ext. angles of a triangle.
4.		$x + 65^o + 30 = 180^o$ $x + 95^o = 180^o$ $x = 180 - 95^o$ $x = 85^o$	Sum of angles of a triangle.
5		$M_2 = 30^o + 42^o$ $M_2 = 72^o$	Sum of the interior angles of a triangle.
6		$b = 90 - 48 = 42^o$ $a = 48^o$	compl. Angles Vertical opposite
7		$a + d = 180^o$ $b = g + i$	Angles of the straight line Vertical opposite angles

APPENDIX C_2: LEARNERS' POST-TEST QUESTIONNAIRE

Instructions:

Use a tick (✓)below the correct word to indicate your experience during the Geometry test

In the basic and mental mathematics test with noise (music), I felt that:	It was confusing	I needed more time	I felt happy	I felt normal	I did not feel happy	Others:

APPENDIX D: MATHEMATICS TEACHERS QUESTIONNAIRE

School Code _____

General Instructions

1. Please answer all questions using (√).

QUESTIONS

Please use (√) to indicate the extent to which you experience Learners classroom noise level during your teaching session of Grade 10 mathematics class.

	Always	Very frequently	Frequently	Occasionally	Rarely	Very rarely	Never
How often **do you experience learners' noise** in your Grade 10 mathematics class?							
How often does learners' noise in your Grade 10 mathematics class turns out **to be disruptive behaviour**?							
How often does learners' noise in your Grade 10 mathematics class turn out to **affect fellow learners' concentration**?							
During the lesson, how often to **feel that times has been lost** because of learners' noise in your Grade 10 mathematics class?							
How often do you **fail to achieve your lesson objective** because of learners' noise in your Grade 10 mathematics class?							
How often do you **feel irritated** because of learners' noise in your Grade 10 mathematics class?							
How often do noise coming from **outside the school premises** affect your lesson delivery for Grade 10 mathematics class?							
How often do noise coming from **inside the school premises** affect your lesson delivery for Grade 10 mathematics class?							

APPENDIX E: LESSON OBSERVATION INSTRUCTION GUIDELINES

APPENDIX F_1: GRADE 10 MATHEMATICS TEACHER'S CONSENT

DATA COLLECTION PHASE: _____ **SCHOOL CODE: ___**

MATHEMATIC TOPIC:

DATE: **TIME:**

SECTION A: Recording the timing of the activities of the lesson and the noise level in dBA

Instructions: Please indicate the (Minimum, Average and Maximum) noise level of each activity the lesson.

LESSON ELEMENTS	DISCRIPTION OF THE ACTIVITY	NOISE LEVEL IN dBA		
		Min.	Aver.	Max.
Learners' settling in the class & Lesson warm up **(5 minutes)**	Learners arrival in the class and settling down			
	Focusing on the mathematical concepts **not related** to the objective of the lesson			
Introduction **(9 minutes)**	Focusing on the mathematical concepts **related** to the objective of the lesson			
Teach / Explore & Practice / Apply **(13 minutes)**	Presentation of the new concept/ whole class discussion **pertinent** to the objective of the lesson			
	Learners work **independently to solve problem related** to the content of the lesson.			
	Learners work **collectively to solve problem related** to the content of the lesson.			
Assessment **(10 minutes)**	Assessing the learners and determine the success of the lesson using the **written tests**			
Closure & Non-instructional **(3 minutes)**	Reflection and wrapping up of the mathematical contents of a lesson			
	Activity not related to mathematics			

SECTION B: Recording learners' classroom behaviour

Instructions: Please use (√) to indicate the extent of learners' misbehaviour observed during the lesson

Descriptions: N: None M: Mild A: Average E: Extreme

TYPES OF DISRUPTIVE BEHAVIOUR	THE IMPACT ON THE LEARNING				TYPES OF OFF TASK BEHAVIOUR	THE IMPACT ON THE LEARNING			
	N	M	A	E		N	M	A	E
Screaming and shouting					Off task (idling)				
Talking and chatting					Sleeping (The head on the table)				
Participating in jokes					Seem to be daydreaming				
Calling out during the lesson					Leaving the classroom				
Purposely making noise to gain attention					Using mobile devices during lesson				
Disturbing other learners					Doing other subjects				
Answering back or questioning instructions					Fidgeting or fiddling with equipment				
Walking around in the classroom									
Others:					Others:				

Dear Grade 10 Mathematics Teacher

My name is Franco Hagoramagara. I am conducting research towards a Doctoral Philosophy in Education (DEd) at the University of South Africa under the supervision of Dr Joseph Dhlamini, who is a lecturer in the Department of Mathematics Education. We are inviting your school to participate in a study entitled, *Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classroom in the Johannesburg*. The aim of this study is to find innovative ways of enhancing a better learning environment of mathematics by controlling the unwanted noise in the classroom. The objective of the study is to measure learners' classroom noise and investigate its effects on Grade 10 learners' performance in mathematics. The study will use the SNR device to control the noise in the classroom with the aim to enhance learners' better performance in mathematics. Your school is one of four schools purposeful sampled to participate in this research.

I plan to observe some lessons in your Grade 10 mathematics classroom. The lesson observation aims to measure the classroom noise during the mathematics lesson. The noise level(s) during the course of a mathematics lesson will be measured and recorded by the researcher. At some point, learners will write tests (audio/ oral, written and visual) to determine the possible impact, if any, of learners' classroom noise on their understanding of some mathematical concepts. We will also request you to complete a questionnaire reflecting on your experiences of teaching mathematics in Grade 10 in the normal day-to-day classroom noise level; thereafter I will compare your teaching experience in a classroom controlled by smart noise regulator. Hence, I invite you to take part in this survey. The findings of the study will assist learners who may struggle to grasp mathematics concepts because of noise level in mathematics classrooms. The findings may also benefit teachers who may find it difficult to effectively impart mathematical knowledge and sometimes struggle to complete the syllabus in mathematics because of inappropriate classroom noise. Furthermore, the findings may also benefit teachers who require a better classroom teaching environment for mathematics. You are kindly requested to complete this survey questionnaire, comprising one section as honestly and

frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the questionnaire which is for research purposes only.

You are not required to indicate your name or organisation and your anonymity will be ensured. All information obtained from this questionnaire will be used for research purposes only and will remain confidential. Your participation in this survey is voluntary and you have the right to omit any question if so desired, or to withdraw from answering this survey without penalty at any stage. After the completion of the study, an electronic summary of the findings of the research will be made available to you on request. Permission to undertake this survey has been granted by the Gauteng Department of education and the Ethics Committee of the College of Education, UNISA. If you have any research-related enquiries, they can be addressed directly to me or my supervisor. My contact details are: 082 676 8126 e-mail: hagoramagarafranco@yahoo.com and my supervisor can be reached at 012 429 2023 Department of Mathematics Education, College of Education, UNISA, e-mail: dhlamjj@unisa.ac.za. Please return completed and signed consent form indicating that you are willing to participate in the study.

Participant ‘s Name (Please print): _____

Participant Signature: _____

Researcher’s Name: (Please print): _____

Researcher’s Signature: _____

Date: _____

APPENDIX F_2: TEACHER'S CONSENT TO PARTICIPATE IN THIS STUDY (Return slip)

I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.
Please tick the box to indicate that you have agreed on the following.

- ☐ I agree to the recording of the data related to classroom noise.
- ☐ I agree to the recording of the observed behavior in the classroom.
- ☐ I agree to complete a questionnaire.
- ☐ I have received a signed copy of the informed consent agreement.

Participant Name & Surname : _____

_____ _____

Participant's Signature Date

Researcher's Name & Surname (please print): Franco Hagoramagara

_____ _____

Researcher's Signature Date

APPENDIX F_3: MATHEMATICS TEACHER'S CONSENT AND CONFIDENTIALITY AGREEMENT

I_____ grant consent that Mr Franco Hagoramagara may use the information I share by completing the questionnaire for research purposes. I am aware that the researcher will be present in classroom while I am teaching. The researcher will record data related to classroom noise. I am also aware that classroom noise level will be digitally recorded and grant consent for these recordings, provided that my privacy will be protected. I undertake not to divulge any information that is shared in this study to any person outside my school in order to maintain confidentiality.

Participant's Name (Please print): _____

Participant Signature: _____

Researcher's Name: (Please print): _____

Researcher's Signature: _____

Date: _____

APPENDIX G: A LETTER REQUESTING PARENTAL CONSENT FOR MINORS TO PARTICIPATE IN A RESEARCH PROJECT

Dear Parent

Your child is invited to participate in a study entitled "*Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classroom in the Johannesburg*".

I am undertaking this study as part of my doctoral research at the University of South Africa. The purpose of the study is to improve Grade 10 learners' performance in mathematics by introducing an innovative way of controlling learners' noise in the classroom and the possible benefits of the study are the improvement of learning atmosphere in mathematics classroom. I am asking permission to include your child in this study because she (he) will be part of Grade 10 class that was sampled to participate in this research. I expect to have about 30 other children participating in the study in the same class and other one hundred children across the Johannesburg Metro. If you allow your child to participate, I shall request him to be present in the classroom during normal period of mathematics lesson and to allow the researcher to observe the lesson and to record classroom noise level. Complete three different mathematics tests which will last 30 minutes altogether. The test will be short audio, visual and written mathematics tests aiming to determine the extent to which classroom noise affect your child's understanding of different topics in mathematics.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His responses will not be linked to his name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only. There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefits to education are the improvement of learning atmosphere for mathematics classrooms. The findings of the study will assist learners who may struggle to grasp mathematics concepts because of noise level in mathematics classrooms. The findings may also benefits teachers who may find it difficult to effectively impart mathematical knowledge and sometime struggle to complete the syllabus in mathematics because of inappropriate classroom noise. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly, you can agree to allow your child to be in the study now and change your mind later without any penalty. The study will take place during regular classroom activities with the prior approval of the school and your child's teacher. However, if you do not want your child to participate, an alternative activity will be available. In this case, your child will be given a choice of different mathematics class activities which is not part of this research. He will assisted perform these activities in the

separate section of the classroom. In addition to your permission, your child must agree to participate in the study and you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study.

Thereafter, records will be erased. The benefits of this study are to find a solution to the problems caused by excessive noise in mathematics classroom which may hinder learners to understand some mathematics concepts. The findings of the study will assist learners who may struggle to grasp mathematics concepts because of noise level in mathematics classrooms. The findings may also benefits teachers who may find it difficult to effectively impart mathematical knowledge and sometime struggle to complete the syllabus in mathematics because of inappropriate classroom noise. There are no potential anticipated risks that may harm the participants. This research will be conducted with great courtesy by the researcher himself, be as non-obstructive as possible and insure that your child feels comfortable to be observed in their natural learning environment or when the SNR device is installed in their classrooms. Learners will voluntarily participate in the study only after learners' assent letter has been signed and the parents have consented. There will be no reimbursement or any incentives for participation in the research.

If you have questions about this study please ask me or my study supervisor, Dr Joseph Dhlamini, Department of mathematics, College of Education, University of South Africa. My contact number is 082 676 8126 and my e-mail is
"hagoramagarafranco@yahoo.com".
The e-mail of my supervisor is "dhlamjj@unisa.ac.za". Permission for the study has already been given by Gauteng Department of Education, School Governing Body, the school Principal and the Ethics Committee of the College of Education, UNISA.

You are making a good decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child:
Sincerely

_____	_____	_____
Parent/guardian's name (print)	Parent/guardian's signature:	Date:
_____	_____	_____
Researcher's name (print)	Researcher's signature	Date:

APPENDIX H_1: PARTICIPANT INFORMATION SHEET (LEARNER'S ASSENT)

Date:
Title: Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classroom in the Johannesburg.

DEAR PROSPECTIVE PARTICIPANT

My name is Franco Hagoramagara and I am doing research under the supervision of Dr Joseph Dhlamini, a senior lecturer in the Department of Mathematics Education towards a Doctoral Philosophy in Education (DEd) at the University of South Africa. We are inviting you to participate in a study entitled "Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classroom in the Johannesburg."

WHAT IS THE PURPOSE OF THE STUDY?

This study is expected to collect important information that could useful to find a solution of the problems caused by excessive noise in mathematics classroom which hinder your child to understand some mathematics concepts.

WHY AM I BEING INVITED TO PARTICIPATE?

You are invited because your school has been identified and selected in the cluster sampling used in this study. Your school fits one of the characteristics used in this study (one school near the railway, one school in the township, one school in the suburb, one school in an old school building). I obtained your school contact details from Gauteng Education Department database. Your school is one of the four school sampled to participate in this study. The intact whole Grade 10 mathematics classroom will be observed; the noise level will be measured and recorded by the researcher.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves the observation of Grade 10 mathematics learners in the classroom setting, learners will involve in audio, written and visual mathematics tests, and a mathematics teacher will complete a questionnaire about Grade 10 learners' performance in mathematics lesson during different level of noise in the classroom. If you agree to participate in this research you will be requested to allow the researcher to observe one class in Grade 10 mathematics and measure the classroom noise during their lessons. Also Grade 10 learners will be asked to perform short audio visual and written mathematics tests to determine the impact of learners' classroom noise in their understanding of some mathematical concepts. Furthermore, you will be asked to complete a questionnaire using (√) to indicate the extent to which the SNR device improved your mathematics teaching experience and learners' participations during mathematics lessons controlled by the SNR device. The classroom observation and the documentation of data related to learners' noise will take place in one teaching period per week for a period of two months. The researcher will not interfere with the delivery of the lesson. The researcher will use the two last observation session to administer to learners' audio, written and visual mathematics tests. Each session of the tests will last one teaching period of 40 minutes. The first session will take place in normal day-to-day

classroom environment and the second session will take place in a classroom environment controlled by the SNR device.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent. The role of the researcher is of non-obstructive observer and only recording data related to classroom level of noise. As a Mathematics teacher you will continue to teach your class without any interference of the researcher. Therefore, it will not be possible to withdraw once you have consented to participate in this study.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

Your participation in this study will be an invaluable contribution in mathematics education because this study aims solutions to multiple factors of concern in the discipline of mathematics education: namely unwanted learners' classroom noise, learners' motivation, and learners' cognitive process of mathematics. The study will develop a Smart Noise Regulator (SNR) device. The device is an innovative way which is intended to regulate learners' inappropriate behaviour in particularly those related to learners' noise in the classroom in South Africa.

ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There are no risks anticipated for this research. This research will be conducted with great courtesy by the researcher himself, be as non-obstructive as possible and insure that your child feels comfortable to be observed in their natural learning environment or when the SNR device is installed in their classrooms. Learners will voluntarily participate in the study only after learners' assent letter has been signed and the parents have consented.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

To maintain confidentiality, the researcher will personally collect all data without any other assisting personnel. The identity of all participants, and that of your school, will not be revealed. In reporting about the findings from this research pseudonyms will be used. Apart from the researcher, no other person outside your school will know about your involvement in this research. Your name will not be recorded anywhere and no one will be able to connect you to the answers you give. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. Your answers may be reviewed by people responsible for making sure that research is done properly, including members of the Research Ethics Review Committee. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records. Also, in reporting the findings of the study the anonymous data may be used for other purposes, such as a research report, journal articles and/or conference proceedings. In this case also the name of the school and the

participants will be kept anonymous. In this study an intact group of Grade 10 mathematics learners will be used. While every effort will be made by the researcher to ensure that you will not be connected to the information of this study, I cannot guarantee that other participants in the group will treat information confidentially. I shall, however, encourage all participants to do so.

HOW WILL THE RESEARCHER PROTECT THE SECURITY OF DATA?

Hard copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet at the researcher's residence in Troyeville, Johannesburg for future research or academic purposes; electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. After five years or in events that data is no longer used for research or other academic purposes, data will be destroyed. Hard copies will be shredded and/or electronic copies will be permanently deleted from the hard drive of the computer through the use of a relevant the software programme.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

Participation in this research is voluntary. There is not any anticipated cost that will incur by the participant. Hence there will be no gifts, incentives or compensations of any kind to reimburse those who will participate in the study.

HAS THE STUDY RECEIVED ETHICS APPROVAL?

This study has received written approval from the Research Ethics Review Committee of the CEDU (College of Education), Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Mr Franco Hagoramagara on 082 676 8126 or email hagoramagarafranco@yahoo.com or at www.unisa.ac.za/repository. The findings are accessible in 2019 or two years after the completion of data collection period. Should you require any further information or want to contact the researcher about any aspect of this study, please contact Mr Franco Hagoramagara on 082 676 8126 or email hagoramagarafranco@yahoo.com.

Should you have concerns about the way in which the research has been conducted, you may contact Dr Joseph Dhlamini: email to dhlamjj@unisa.ac.za or phone 012 429 2023.

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.

_____

Franco Hagoramagara

APPENDIX H_2: LEARNERS' ASSENT TO PARTICIPATE IN THIS STUDY (Return slip)

I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary.
I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the data related to classroom noise.
I agree to the recording of the observed behaviour in the classroom.
I have received a signed copy of the informed assent agreement.

Participant's Name & Surname _____

_____ _____
Participant's Signature Date

Researcher's Name & Surname (please print): Franco Hagoramagara

_____ _____
Researcher's Signature Date

APPENDIX H_3: A LETTER REQUESTING ASSENT FOR LEARNERS IN A SECONDARY SCHOOL TO PARTICIPATE IN A RESEARCH PROJECT

Title of research: *Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classroom in the Johannesburg.*

Dear Learner Date _____

I am conducting a study on ways to improve Grade 10 learners' poor performance in mathematics as part of my studies at the University of South Africa. Your principal has permitted me to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways to determine the appropriate classroom noise level for better understanding of mathematics during the lessons. This study will assist in developing a device to assist teacher in controlling noise level in mathematics classroom so that more meaningful learning of mathematics takes place. The findings of the study will assist learners who may struggle to grasp mathematics concepts because of noise level in mathematics classrooms. The findings may also benefits teachers who may find it difficult to effectively impart mathematical knowledge and sometime struggle to complete the syllabus in mathematics because of inappropriate classroom noise. This may help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study. I would like to ask you to present in the classroom and to allow the researcher to observe the lesson and record classroom noise level during your normal mathematics lesson. The researcher will be visiting your classroom one day per week for duration of two months. The noise recording and the lesson observation will last only 40 minutes per day. I would like also to ask you to participate in the short audio visual and written mathematics tests to determine the extent to which classroom noise affect your understanding of different topics in mathematics. The 3 tests will no longer than 30 minutes altogether. The tests will be administered in two different periods. I will write a report on the study but I will not use your name in the report or say anything that will let other people know who you are. Participation is voluntary and you do not have to be part of this study if you don't want to take part. If you choose to be in the study, you may stop taking part at any time without penalty. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

The benefits of this study are to improve learners' performance in mathematics by constructing model and a device that will control noise in mathematics classroom so that meaningful learning can take place in mathematics classroom. There are no risks involved in this study. The study will be conducted in the normal classroom environment. You will not be reimbursed or receive any incentives for your participation in the research.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can ask your parent or another adult call me at 082 676 8126.Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher: _____ Phone number: _____

Do not sign the written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

APPENDIX H_4: WRITTEN ASSENT

I have read this letter which asks me to be part of a study at my school. I have understood the information about my study and I know what I will be asked to do. I am willing to participate in the study.

_____ _____ _____
Learner's Name (print): Learner's Signature: Date:

_____ _____ _____
Witness's Name (print) Witness's Signature Date:

(The witness is over 18 years old and present when signed.)

_____ _____ _____
Parent/guardian's Name (print) Parent/guardian's Signature: Date:

_____ _____ _____
Researcher's Name (print) Researcher's Signature: Date:

APPENDIX I: TEACHERS' QUESTIONNAIRE ANALYSIS SHEET

	Max. code	7	6	5	4	3	2	1	Mean range
		Always	Very frequently	Frequently	Occasionally	Rarely	Very rarely	Never	
	Likert scale range	$6 < r \leq 7$	$5 < r \leq 6$	$4 < r \leq 5$	$3 < r \leq 4$	$2 < r \leq 3$	$1 < r \leq 2$	$0 < r \leq 1$	
How often **do you experience learners' noise** in your Grade 10 mathematics class?			E	F	B		A C D		3,5
How often do learners' noise in your Grade 10 mathematics class turns out **to be disruptive behaviour**.			E		B F	C D	A		3,7
How often do learners' noise in your Grade 10 mathematics class turns out to **affect fellow learners' concentration**.			E	F	B	C	A D		3,7
During the lesson, how often do you **feel that time has been lost** because of learners' noise in your Grade 10 mathematics class?		F	E		B	A	C	D	3,8
How often do you **fail to achieve your lesson objective** because of learners' noise in your Grade 10 mathematics class?					E	F	A	B C D	2
How often do you **feel irritated** because of learners' noise in your Grade 10 mathematics class?				E	A B	F	C D		3,3
How often do noise from **outside the school premises** affect your lesson delivery for Grade 10 mathematics class?					D E		B C F	A	2,5
How often do noise from **inside the school premises** affect your lesson delivery for Grade 10 mathematics class?				C	A D E		B F		3,5
How often do you ignore learners' noise and carry on with the lesson in your Grade 10 mathematics class?				E			C	A B D F	1,8
How often do some learners complain that they can't hear you because the level of noise in Grade mathematics class is high?			F			E	A	B C D	2,3

APPENDIX K: GAUTENG DEPARTMENT OF EDUCATION RESEARCH APPROVAL LETTER

8/4/4/1/2

GDE AMENDED RESEARCH APPROVAL LETTER

Date:	14 February 2019
Validity of Research Approval:	04 February 2019 – 30 September 2019 2017/32A
Name of Researcher:	Hagoramagara F
Address of Researcher:	8 Beryl Court
	24 Pretoria and Beelaert streets
	Troyeville
	Johannesburg, 20194
Telephone Number:	082 676 8126
Email address:	hagoramagarafranco@yahoo.com
Research Topic:	Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classrooms
Type of qualification	PhD
Number and type of schools:	Five Secondary Schools
District/s/HO	Johannesburg Central and Johannesburg East

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

APPENDIX L: ETHICAL CLEARANCE CERTIFICATE FROM UNISA

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2017/08/16

Ref: **2017/08/16/53734106/30/MC**
Name: Mr F Hagoramagara
Student: 53734106

Dear Mr Hagoramagara

Decision: Ethics Approval from 2017/08/16 to 2022/08/16

Researcher:

Name: Mr F Hagoramagara
Email: hagoramagarafranco@yahoo.com
Telephone: 082 676 8126

Supervisor:
Name: Dr JJ Dhlamini
Email: dhlamjj@unisa.ac.za
Telephone: 012 429 2023

Title of research:

Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classrooms in the Johannesburg metropolitan

Qualification: D Ed Mathematics Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2017/08/16 to 2022/08/16.

The low risk application was reviewed by the Ethics Review Committee on 2017/08/16 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

APPENDIX M: LANGUAGE EDITING CERTIFICATE

7542 Galangal Street
Lotus Gardens
Pretoria
0008
19 August 2020

TO WHOM IT MAY CONCERN

This certificate serves to confirm that I have edited Franco Hagoramagara's thesis entitled, Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classroom in the Johannesburg.

I found the work easy and intriguing to read. Much of my editing basically dealt with obstructionist technical aspects of language, which could have otherwise compromised smooth reading as well as the sense of the information being conveyed. I hope that the work will be found to be of an acceptable standard. I am a member of Professional Editors' Guild.

Hereunder are my particulars:

Jack Chokwe (Mr)
Contact numbers: 072 214 5489
jackchokwe@gmail.com

Professional EDITORS Guild

APPENDIX N: PROOF OF REGISTRATION

UNISA university of south africa

1235 MDRES

HAGORAMAGARA F MR
8 BERYL COURT
24 BEELAERT STREET
JOHANNESBURG
2001

STUDENT NUMBER : 5373-410-6

ENQUIRIES NAME : M&D ADMIN SUPPORT
ENQUIRIES TEL : (012) 441-5702

DATE : 2021-03-15

Dear Student

I wish to inform you that your registration has been accepted for the current academic year. No printed material is available for the compulsory module in Research Methodology. Kindly activate your Unisa mylife account for future communication purposes and access to study material (https://myunisa.ac.za/portal).

DEGREE : PHD (EDUCATION) (90019)

TITLE : Using a smart noise regulator to mitigate learners' poor performance in Grade 10 mathematics classrooms

SUPERVISOR : Dr JJ DHLAMINI (dhlamjj@unisa.ac.za)

ACADEMIC YEAR : 2021

TYPE: THESIS

SUBJECTS REGISTERED: TFPCU01 PhD - Education (Curriculum Studies)

The outcome of the compulsory research proposal module is the submission of an acceptable research proposal (a final research title will be approved and supervisor(s) will be appointed). On official approval of the result, you will be allowed to register for the research component within the prescribed registration period. Please access the information with regard to your personal librarian on the following link: http://www.unisa.ac.za/libinfomd\.

Yours faithfully,

Prof M S Mothata
Registrar

APPENDIX O: TURNITIN SIMILARITY INDEX REPORT

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Page count:	274
Word count:	75,006
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Submission date:	04-Nov-2020 08:14AM (UTC+0200)
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USING A SMART NOISE REGULATOR TO MITIGATE LEARNERS' POOR PERFORMANCE IN GRADE 10 MATHEMATICS CLASSROOMS

by

FRANCO HAGORAMAGARA

Submitted in accordance with the requirements of the degree of Doctor of Philosophy in Education (PhD)

in the subject

MATHEMATICS EDUCATION

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: DR JOSEPH J DHLAMINI