CLASSROOM ACOUSTICS IN GHANA: THE CASE OF SEVEN SELECTED SCHOOLS IN THE GREATER ACCRA REGION

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THIS DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTERS OF SCIENCE IN AUDIOLOGY

JULY 2018
DECLARATION

I, CATHERINE SENYASU, do hereby declare that this thesis which is being submitted in fulfillment of the requirements for the Master of Science degree in Audiology is the result of my own research performed under supervision, and that except where otherwise other sources are acknowledged and duly referenced, this work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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DEDICATION

I dedicate this work to my husband Mr. Emmanuel Kokroko Hammond, my children Elsie Nana Ama Obuo Hammond, Ethan Kwesi Kokroko Hammond, and Elaine Yaa Adepa Hammond.
ACKNOWLEDGEMENT

My utmost thanks go to the Almighty God for sustaining me throughout the program successfully. I wish to acknowledge Dr. Yaw Nyadu Offei and Dr. Samuel Anim-Sampong my supervisors for their guidance, support, knowledge and contributions.

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LIST OF ABBREVIATIONS

ANSI          American National Standards Institute
ASHA          American Speech-Language-Hearing Association
dBA           Decibel A-weighted
WHO           World Health Organization
CDD           Center for Democratic Development
SNR           Signal-to-noise ratio
L_{eq}        Equivalent sound pressure level
RT            Reverberation time
SPL           Sound pressure level
DEFINITION OF TERMS

Acoustics: the properties or qualities of a room or building that determine how sound is transmitted in it.

Reverberation: echoing or prolongation of a sound.

Signal-to-noise ratio: the ratio of the strength of speech to that of background noise.
ABSTRACT

Background: Classroom acoustics is essential aspect of the learning environment. A poor acoustical environment can impede a child’s ability to listen and learn. Excessive reverberation and background noise can affect the educational performance and achievement of children with hearing loss and normal hearing. It can also lead to teacher fatigue, stress and increase their chances of acquiring voice and throat problems since they have to raise their voices to be heard by the children.

Aim: This study aimed at analyzing the acoustic characteristics of selected classrooms in the Greater Accra region of Ghana and to compare with the standards set by ANSI and ASHA.

Methodology: Purposive sampling was used to select 7 schools while simple random sampling was used to select 28 classrooms within the schools. The acoustic condition of all selected classrooms was assessed using a calibrated Optimus Sound Level Meter to measure the background noise and signal-to-noise ratio. Reverberation time was measured using Room EQ Wizard software. The readings recorded were compared with ANSI and ASHA standards using one sample t-test at 95% confidence level.

Results: The average background noise in occupied and unoccupied classroom was 65 dBA and 47.5 dBA respectively. The average Leq was 87.6 dBA whiles the average SNR was +7 dBA. The average reverberation time was 0.77 seconds. There was a statistically significant difference between these averages and the standards set by ANSI and ASHA (p < 0.05).

Conclusion: All the classrooms that were assessed did not meet the recommended international standards for classroom acoustics. This will hinder effective teaching and learning and therefore requires appropriate intervention.

Keywords: Reverberation time, signal-to-noise ratio, classroom, acoustic, noise
CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

The future of every nation depends on the health and education of its children. There are several challenges facing education and health-delivery to children in Ghana. One of such problems is poor classroom acoustics. In particular, classroom acoustics is a very important aspect of the learning environment but it is often neglected. About sixty percent of activities in the classroom involve spoken language or verbal communication between the teachers and school children or between children themselves. For ideal academic achievement, the accurate transmission of acoustical information in a classroom is crucial. There is therefore the need to have good acoustic environments that support speech intelligibility (Decor Systems, 2017).

Poor acoustic environment can deter a child’s ability to hear and learn. Excessive reverberation and ambient noise can affect the educational performance and achievement of children with impaired hearing and those with normal hearing (Knecht, Nelson, Whitelaw, & Feth, 2002). Both children with or without learning difficulties and hearing disability are affected by poor classroom acoustics environment (Knecht, Nelson, Whitelaw, & Feth, 2002).

Noise in the environment creates nuisance and stress. In schools, noise exposure is often at a high risk level. According to Sundaravadhanan, Selvarajan, & McPherson (2017), noise in schools can be grouped into two broad types; internal and external noise. Sources of internal noise include student conservation, desks movement, humming of lights, ceiling or wall fans whiles external noise result from road traffic, lawn mowers, birds, nearby playground and
construction sites. These internal and external noises add up to the background noise in a classroom setting which affects speech intelligibility.

Nelson & Soli (2000) stated that adequate speech recognition by children in the classroom is essential for learning. Unfavourable listening environments are more detrimental to younger children compared to other populations due to development of auditory and linguistic skills. Also, background noise competes with the teacher’s voice which compromises the quality of speech heard by the children. The teachers, on the other hand will have to raise their voices to be heard by the children. This increases teacher fatigue, stress, and increases the chances of developing voice problems (Guidini, Bertoncello, Zanchetta & Dragone, 2012; Kristiansen et al, 2014).

The crucial effects of noise are speech interference, disturbance of information extraction such as reading acquisition, comprehension, transmission of message and annoyance. In order to hear and understand speech in the classroom, the signal-to-noise ratio (SNR) should be +15 dB (ANSI, 2010). The reverberation time (RT) in the classroom should be about 0.6 seconds, and preferably lower for children with impaired hearing (Berglund, Lindvall, Schwela, & OMS, 1999). The British Association of Teachers of the Deaf (2001) recommends that unoccupied background noise should not be above 35 dB (A) and RT should not be above 0.4s in the frequency range of 125Hz to 4000Hz. SNR should not be above 20 dB in the frequency range of 125Hz to 750Hz and 15 dB in the frequency range of 750Hz to 4000Hz. In Ghana, no specific standard for classrooms has been documented.

An assessment of public basic schools in five regions of Ghana by Center for Democratic Development (CDD) revealed that most schools did not meet basic standards such as adequate classrooms, proper ventilations, floors and ceilings of schools have poor classroom acoustics as a
result of poor quality or absent acoustics ceiling tiles, flat floors and windows. (Ghana News Agency, 2013). They recommended that government should examine, strengthen and implement policies that are geared towards ensuring quality educational outcomes (Ghana News Agency, 2013). Good classroom acoustics are basic needs since children who acquire language skills in poor classroom acoustics conditions may develop long-term speech understanding problems. However, this has not been given the needed attention in Ghana and hence classroom acoustics is not considered in the planning and construction of schools.

1.2 PROBLEM STATEMENT

Children spend about 60% of their working hours in school. They depend on speech and comprehension in their learning activities. They need to always segregate the relevant signal from the ambient noise (Decor Systems, 2017). In schools, the classrooms are often filled with deterrents that inhibit a child’s ability to hear and learn. Excessive reverberation and background noise can affect the educational performance and achievement of children with hearing problems and even those with normal hearing (Knecht et al., 2002). Children with learning, attention or reading deficits or using English as a second language are also affected.

In Ghana, most classrooms are not acoustically treated which leads to teachers to raising their voices and increasing teacher stress and fatigue. Most of the schools are also located close to noise sources such as main roads and markets. Currently, no study has evaluated the acoustic situations in classrooms in Ghana to ascertain if they meet international standards.

1.3 SIGNIFICANCE OF THE STUDY

Firstly, this study will provide information about the acoustic situations of some classrooms in Accra. This will help create awareness for acoustical design in school planning and the need for
policy-makers to allocate resources to achieve a realistic target for classroom acoustic situations in order to influence existing or new building regulations at the local, regional and national levels.

Secondly, the study will support the need to include educational audiologists, acousticians and special education teachers in the planning, sitting and construction of schools in the country. This will eventually lead to the establishment of classrooms with conducive acoustic environment for teaching and learning. In addition, the findings of this study will serve as baseline information for future related studies and help bridge the gap in literature with regards to classroom acoustics in Ghana.

1.4 HYPOTHESES

• H₁: There will be ≤ 15dB SNR in the classrooms in Accra.
• H₂: There will be ≥ 0.6 seconds reverberation time above the recommended standard.
• H₃: There will be ≥ 35dB background noise in unoccupied classrooms in Accra.

1.5 AIM OF THE STUDY

This study aims to analyze the acoustic characteristics of classrooms and to compare with standards set by ANSI and ASHA.

1.6 OBJECTIVES OF THE STUDY

The objectives of the study were;

• To assess the background noise in occupied and unoccupied classrooms in Accra.
• To assess the reverberation time in the classrooms.
• To assess the SNR from the teachers to the students.
• To compare the acoustic parameters measured with international standards.
CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION
This Chapter reviews the literature relevant to this study. It covers the acoustic variables in classroom settings, background noise and their sources, reverberation, signal-to-noise ratio, classroom acoustics standards, effects of noise on academics and teacher performance and acoustics improvement.

2.2 ACOUSTIC VARIABLES IN CLASSROOM SETTINGS
The transmission of acoustical information is essential in the classroom setting in order to achieve academic goals. However, the acoustic characteristics of the classroom environment may affect speech quality of children with normal hearing and those with impaired hearing (Crandell & Smaldino, 2000). Today, students are able to understand 75% of teachers instructions due to background noise and reverberation, resulting in reduced learning (Acoustical Society of America, 2000). Some acoustic variables that can hinder speech intelligibility and perception in the classroom setting include background noise, RT, SNR and speaker-listener distance.

2.3 BACKGROUND NOISE
This refers to any auditory disturbance within the room that interferes with what a listener wants to hear” (Smaldino & Flexer, 2012). In a classroom setting, background noise consists of all ambient noise in the classroom generated internally, externally and room sources, but not by the primary instructional medium (normally the teacher). These external noises could come from automobile traffic, lawn mowers, birds, nearby playground, airplane traffic and construction sites. Internal noises are within the building, but outside of the classroom such as children play ground,
other classrooms and hallways. Sources of noise produced in the classroom can be the hum of lights, ceiling or wall fans, and even noise made by the students (Crandell & Smaldino, 2000; Smaldino, Kreisman, John, & Bondurant, 2015). Background noise in the classroom mask the weaker transient consonant phonemes more than the longer and more intense vowels (Smaldino et al., 2015). According to French and Steinberg (1947) “a reduction of consonant information can have a significant impact on speech perception because approximately 80% to 90% of the acoustic information important for speech perception comes from the consonants”.

A study by Crandell & Smaldino (1995) revealed that background noise values measured in 32 unoccupied classrooms were 51 dBA and 67 dBC and higher compared with the 35 dBA and 55 dBC set by the ANSI in 2002 and endorsed by ASHA in 2004 (ASHA, 2004). Though the Environmental Protection Agency in Ghana has set national ambient noise level permissible in educational facilities during the day at 55 dB (A) and 50 dB (A) at night, no study was found in the literature to show compliance. Building materials used in constructing most of the schools in Ghana are not designed as acoustic barriers, while locations of some of the schools are not acoustically friendly, because the opened windows and doors always permit environmental noise into the classroom to disrupt effective teaching and learning.

2.3.1 Sources of Background Noise

Sources of noise in classrooms could arise from adjacent classroom walls, over ceilings, doors (under and around door frames), ventilators or louvers above door units, heating ventilation and air condition (HVAC), duct work from adjacent rooms, HVAC noise from ceiling diffusers, light fixtures, exterior walls and windows, and higher floors (Figs. 2.1 and 2.2).
Figure 2.1: Ambient or background noise level

Source: Tiesler & Oberdörster, (n.d.)
Figure 2.2: Sources of background noise in the school

Source: Tiesler & Oberdörster (n.d.)
2.4 REVERBERATION

Another acoustic variable impacting on speech perception in the classroom is reverberation. It refers to “the prolongation or persistence of sound within an enclosure when sound waves reflect off hard surface (e.g., bare walls, ceilings, windows, floors)” (Smaldino et al., 2015 p. 677). Most often reverberations are referred to as an echo. RT is defined as the amount of time (seconds) it takes for a sound of a specific frequency to reduced by 60 dB after the source has ceased (Crandell & Smaldino, 2000; Smaldino et al., 2015). For example, if a sound of 100 dB sound pressure level (SPL) at a frequency of 1000 Hz takes 1 second to decrease to 40 dB SPL, then the reverberation time (RT) of that room at 1000 Hz is 1 second.

According to Nixon (n.d.), sound generates spherically in all directions just as blowing up a very large balloon. Sound waves travel at about 770 miles per hour (1232 km/hr) in the air. When these waves contact a hard surface, they are reflected many times until the sound energy is absorbed and can no longer be heard. It is very easy to hear reflected sounds in a large voluminous space in the form of hissing or even a clicking sound. Sounds in any untreated voluminous space immediately echoes or reverberate. This also happens in smaller classrooms but is very difficult to detect. The reflections of sounds arriving at the student’s ear during continuous speech are milliseconds after the direct speech sound tend to smear the clarity of the speech signal. Nixon, (n.d.) stated that the reflected sounds can sound louder than the direct speech signal when is beyoud critical distance of the direct speech.

The ANSI S12.60-2002 code revised in 2010 recommends an RT of an unoccupied classroom at 0.6s in smaller classrooms or 0.7s in larger classrooms. Sound that takes a longer time to reveberate makes it difficult to hear especially in a noisy background. Extreme RT in the
classroom creates extra disturbance due to acoustic reflections. The desired signal is temporally spread due to reflections, which can lead to a rise in background noise values (ASHA, n.d.)

The ability of the room to draw up the energy that is put into the room decides how much interference the residual energy will impede in the learning environment. RT becomes greater in rooms with bare floors and high ceilings. The longer that it takes the sound to reverberate, the difficult it is for the sound to be audible, especially if there are multiple sounds (such as the background noise) reverberating. Older classrooms usually have high ceilings and bare floors. The newer classrooms are however denied carpeting due to bacterial concerns. These smooth surfaces in the classroom will increase the RT, degrading the child’s speech quality.

Researchers have shown that children with and without impaired hearing have difficulty comprehending speech in unamplified rooms with typical reverberance and background noise (Knecht, Nelson, Whitelaw, & Feth, 2002). Most classrooms in Ghana do not have carpets, curtains on windows, and ceilings made of acoustic material to absorb the noise. The bare smooth surfaces could increase the reverberation time reducing speech perception in the classroom setting.

2.5 SIGNAL-TO-NOISE RATIO (SNR)

The link between the intensity of a signal and the intensity of background noise at a child’s ear is most important in speech perception (Crandell & Smaldino, 2000). This relationship is referred to as the SNR. In the classroom setting, the signal is the instructions of the teacher. To illustrate this, if the voice of a teacher teaching in a classroom is at 75 dB and the background noise in the class is about 65 dB then the SNR is +10 dB. Increased background noise will reduce SNR as well as an increase in reverberation will also reduce SNR, which will compromise speech
perception in the classroom. The American National Standard Institute recommends a SNR of +15 dB at the child’s ear to determine speech intelligibility. This shows the evidence between a child’s ability to hear and an adult’s ability to hear. Normal hearing children require an SNR of +15 dB whiles normal hearing adults need an SNR between +4 and +6 dB. So a teacher needs to speak at least 9 dB louder for children in the classroom than adults need the teacher to speak in order to fully understand the spoken language.

According to the Armstrong Ceiling Solution (2003), SNR is useful to determine the quality of spoken language in a room. To evaluate SNR the sound level of the teacher’s voice in dB, is subtracted from the background noise level in the room (dB). The greater the SNR, the larger the speech quality. If the background noise is louder than the teacher’s voice (that is if SNR negative) the teacher will be hard to understand. SNR varies throughout the room as the signal and noise levels vary. Usually, SNR is lowest either at the back of the classroom, where the level of the teacher’s voice has decayed to its reduced value or near the noise source, where the noise level is at its peak. Research has shown that classrooms having a SNR of less than +10 dB, speech is significantly reduced for children with average hearing to understand. Hearing impaired children need at least +15 dB SNR (ANSI, 2010).

2.6 SPEAKER-LISTENER DISTANCE

The distance between the teacher and the children also influence speech perception in classroom settings. If the teacher is close to the child, the direct sound field predominates in the listening environment, so there is minimal interference from the classroom surfaces (Crandell & Smaldino, 2000). This is the principle of the inverse square law, which states that sound level reduces by 6 dB for each doubling of distance from the source of sound. So, the further the child is from the teacher (source of signal) the poorer the speech perception. This is why one simple
recommendation of seating arrangement in the classroom setting is not enough to ensure effective speech perception. So teachers have to walk around the classroom when talking and not talk when writing on the chalkboard. The inverse square law is depicted in Fig. 2.3

![Inverse square law graph]

**Figure 2.3: Inverse square law**

Source: The Institute for Enhanced Classroom Hearing (n.d.)

2.7 CLASSROOM ACOUSTICS STANDARDS

According to the standard, the maximum permissible one-hour average background noise is less or equal to 35 dB (A) (55 dB C) and maximum RT for SPL in octave bands with midBand frequencies of 500, 1000, and 2000 Hz is 0.6 s for a classroom with size less than or equal to 10000 cubic feet (ft$^3$) and an RT of 0.7 s. If the classroom is above 10000 ft$^3$ but below or equal to 20000 ft$^3$ (ANSI), 2010). The international guidelines for classroom acoustics are presented in Table 2.1.

Table 2.1: International guidelines for classroom acoustics

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<tr>
<th>Acoustical components</th>
<th>ASHA Guidelines</th>
<th>ANSI Guidelines</th>
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<tr>
<td>Background Noise</td>
<td>35 dBA unoccupied room</td>
<td>35 dBA unoccupied room</td>
</tr>
<tr>
<td>RT</td>
<td>≤ 0.4</td>
<td>≤ 0.6s (small rooms)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7s (large rooms)</td>
</tr>
<tr>
<td>SNR</td>
<td>≥ +15</td>
<td>Not addressed</td>
</tr>
</tbody>
</table>

During communication in classrooms that are carefully built following acoustical design, the difference between the sound levels and the background noise will be +15 dB, which means the sound level will be 15 dB greater than the background noise. In such classrooms, every student including those with hearing problems will have full access to auditory information (Nelson and Soli, 2002). In order for teachers' voice to be intelligible in a room where the background noise is around 45 dBA, the teachers would have to increase their voice to around 65 dB and to speak loudly but not shouting could reach up to 75 dBA. According to Nelson (2003), noise is considered unhealthy when it gets to above 70 dBA, which can cause physiological reactions like stress, stroke, hearing loss, and dysphonia.
From the analysis of many studies, the Acoustical Society of America recommends that using SLM set to the A-weighting scale to measure a room, the overall sound levels that are the target speech and the background noise should not exceed 70 dBA (Nelson & Soli, 2002). In the construction of new schools in Ghana, both architectural and mechanical designs should meet these standards to ensure good acoustic environment for classrooms and other learning facilities. Already existing classrooms should also be upgraded to meet these standards. This will improve teaching and learning, making teaching less stressful. Pictures of some classrooms in Accra are shown in Figures 2.4 and 2.5.

![Figure 2.4: Occupied classroom](http://ugspace.ug.edu.gh)
2.8 EFFECT OF NOISE ON ACADEMICS AND TEACHER PERFORMANCE

Poor classroom acoustic design can produce extreme noise that is disturbing to the learning activity and affects intelligibility, behavior of student and performance of their education. On the other hand, good classroom acoustics design increases speech quality and reduce background noise to protect speech intelligibility for students and teachers. Speech quality in the classroom is based on building designs which include shape, size, and treatment of the surfaces. Poor classroom acoustics can have a negative effect on all students, not just those with hearing impairment. Teachers are at risk for vocal injury since they use their voices most of the time in the learning settings as they need to talk over the background noise to be heard by children (ASHA, n.d.).

Poor acoustic classrooms can have a negative effect on learning within the classroom environment, especially in primary schools (Sharma, 2016). Noise Internal or external can affect
verbal and non-verbal activities, including the perception of speech, reading, and attention (Crandell & Smaldino, 2000). The effect of background noise and high level acoustic reverberation in the classroom is particularly severe on children with impaired hearing, auditory processing disorder, learning difficulty, developmental disabilities or using English as a second language (Crandell & Smaldino, 2000; Nelson & Soli, 2000; Sharma, 2016). In Ghana, English is a second language so most of the school children will be facing such problems.

The effects of poor acoustic classroom can have negative effects that are not limited to children alone, teacher stress, fatigue, annoyance, poor hearing status, and susceptibility to voice disorders are other reported problem (Enmarker & Borman, 2004; Sharma, 2016; Sundaravadhavan et al., 2017). A study conducted by Valentine et al. (2002) on classroom acoustics in New Zealand, showed that 71% of teachers reported that noise created within the classroom is a problem, 35% complained that their voices are strained as a result of the high levels needed to speak, another 61% complained that most of the noise generated inside the classroom are from the student, and another 86% of the teachers had problems with noise outside the classroom, from nearby corridors, classrooms, desks, sports field, lawnmowers, and road traffic noise. The situation in Ghana will not be different considering the poor acoustic nature of the classrooms.

According to Berglund and colleagues (1999), noise causes speech interference which interrupts the dissemination of information. For speech to be audible and understandable in the classroom, the background noise should not be more than 35 dB Leq during learning activities. For children with hearing problems, the sound signal should be lower than 0.6 seconds. RT is needed in the classroom and ideally, it should be lower for hearing impaired children. Indeed, RT greater than
0.4s – 0.6s decrease speech intelligibility in both quiet and noisy environment. Studies have shown that children with speech impairment, language, and hearing disabilities require SNR at least 3 dB above the recommended to offset their vulnerability to the negative effect of RT as compared with children without impairment (Plomp, 1986, Finitzo-Hieber and Tillman, 1978).

Young children are more vulnerable to the effects of background noise and reverberation on spoken language than adults. Due to this vulnerability, young children will require more favorable classroom SNR and RT to acquire the same level of speech intelligibility as adults. The greater vulnerability of young children to background noise and reverberation are due to their developmental status, linguistic and cognitive proficiency early expressive and receptive language disorders. A study by Maxwell & Evans (2000) compared the performance of children in child-care centers with acoustically treated and non-treated classrooms. They observed that children in the treated rooms scored higher in number-letter-word recognition after a year of decrease noise exposure than their mate in the non-treated rooms. Figure 2.6 illustrates the need to improve acoustics in a classroom.
2.9 CLASSROOM ACOUSTICS IMPROVEMENT

The Acoustical society of America published a detailed American National Standard ANSI S12.60-2002 (American National Standards Institute, 2002). These documents include:

- The highest acceptable RT should be 0.6s. An acoustical ceiling tile is the most acceptable and helpful sound absorptive surface which can soak up excess reverberation. However sound reflective material above the teacher and center of the classroom can be selected to help support and project the teacher’s voice to the students.

- Classrooms having their ceiling heights below 10ft will usually have acceptable RT with acoustical tile throughout.

- Classroom with their ceiling height from 12 to 14ft will typically need some additional absorptive material on the side walls together with the acoustical ceiling tile.
• Classroom ceiling heights 15ft and above will need significant quantities of sound absorption treatments like 1” fabric wrapped fiberglass wall panels or equivalent

• The interior and exterior walls in the classrooms, they must meet or be above Sound Transmission Class Rating STC-50. STC is the legally tested sound insulation rating for a given floor, ceiling, wall, door and window assembly.

• Exterior windows must be assessed based on existing background noise levels and total glazes area

• Reverberation in the classroom can be controlled by using carpet on the floors. This can also help decrease footfall noise to classrooms below and reduce noise from moving chairs and feet. However, carpeting does not absorb low frequency sound effectively and may need an additional quantity of acoustical ceiling tile or wall panels. By placing neoprene or rubber on chair legs tips, can decrease chair-shuffling noise on a hard floor surface.

During learning activity, sounds from other children, road traffic noise and market area can interfere with teaching. According to Brown, (2016) speech intelligibility decrease four rows back from the front of the average classroom. This problem exacerbates when children have impaired hearing.

Children are more vulnerable to ear infections especially otitis media (OM) which causes temporary conductive impairment. Studies have identified OM as the most common health disorder in young children which is approximated as high as 25%-30% in kindergarten and first grade children (Schappert, 1992). Other studies identified an incidence above 10% of mild high-frequency sensorineural hearing loss in children between 6- 19 years of age (Ries, 1994). Improving SNR by 3 to 5 dB together with increased absolute speech signals of 10 to 30dB is
important for children with impaired hearing to achieve the same level of speech intelligibility in the classrooms with high background noise.

Teachers face persistent amount of noise throughout their teaching life. They always have to increase their voices higher than that of students and background noise. Long RT in classrooms has led to as much as 50% loss in speech intelligibility (Jordan, n.d.). This affects the children’s ability to concentrate and make the most out of their school time. By installing acoustic absorbers in the classroom, speech intelligibility can increase remarkably. Research has shown that by improving classroom refurbishment, it will decrease RT and improve speech intelligibility and even meeting the international standards for integrative schooling of children with speech impairment. In other words, good classroom acoustics can enhance education. By amplifying the teachers’ voice, they can be heard above the background sounds and it will help when the teacher is addressing the entire class but it will not solve the high background noise problem.

Noise outside the classroom can be very disturbing. Road traffic noise, construction noise and children playing in the corridors cannot be controlled. Mostly doors and windows are the culprits for allowing sounds from outside into the classroom. Sound reducing glass can be installed instead of windows or door seals can be installed to close the gap under and around the door to decrease the amount of external noise than can be heard in the classroom (Brown, 2016).

When selecting sites for learning activities, ANSI S12.9/Part 5 (American National Standards Institute, 1998) recommends that the yearly A-weighted day-night average sound level of the place should not be above the following limits with corresponding construction methods:
• 60 to 65 dB for conventional methods for learning facility with a minimum Sound Transmission Class Rating of 50.

• 65 to 75 dB if the external shell of the learning facility is designed to provide adequate noise insulation in order to limit background noise levels.

• Under no conditions should a new learning facility be located at a site where the yearly average A-weighted day-night sound level exceeds or is predicted to exceed 75 dB.

The minimum surface area of acoustical treatment for different sound absorption coefficients, ceiling heights, and reverberation times at 0.6s and 0.7s are presented in Figure 2.7 and 2.8 respectively.
Figure 2.7: Reverberation time $T_{60}$ of 0.6s

Source: Peggy (2003)
### Figure 2.8: Reverberation time $T_{60}$ of 0.7 s

<table>
<thead>
<tr>
<th>Sound absorption coefficient, $\alpha_1$</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling height, $H$, ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.44</td>
<td>91</td>
<td>107</td>
<td>122</td>
<td>138</td>
<td>154</td>
<td>169</td>
<td>185</td>
<td>200</td>
<td>216</td>
</tr>
<tr>
<td>2.74</td>
<td>82</td>
<td>96</td>
<td>110</td>
<td>124</td>
<td>138</td>
<td>152</td>
<td>166</td>
<td>180</td>
<td>194</td>
</tr>
<tr>
<td>3.05</td>
<td>75</td>
<td>87</td>
<td>100</td>
<td>113</td>
<td>126</td>
<td>138</td>
<td>151</td>
<td>164</td>
<td>177</td>
</tr>
<tr>
<td>3.35</td>
<td>68</td>
<td>80</td>
<td>92</td>
<td>104</td>
<td>115</td>
<td>127</td>
<td>139</td>
<td>150</td>
<td>162</td>
</tr>
<tr>
<td>3.66</td>
<td>63</td>
<td>74</td>
<td>85</td>
<td>96</td>
<td>106</td>
<td>117</td>
<td>128</td>
<td>139</td>
<td>149</td>
</tr>
<tr>
<td>3.96</td>
<td>59</td>
<td>69</td>
<td>79</td>
<td>89</td>
<td>99</td>
<td>109</td>
<td>119</td>
<td>129</td>
<td>139</td>
</tr>
<tr>
<td>4.27</td>
<td>55</td>
<td>64</td>
<td>73</td>
<td>83</td>
<td>92</td>
<td>102</td>
<td>111</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>4.57</td>
<td>51</td>
<td>60</td>
<td>69</td>
<td>78</td>
<td>86</td>
<td>95</td>
<td>104</td>
<td>113</td>
<td>121</td>
</tr>
<tr>
<td>4.88</td>
<td>48</td>
<td>57</td>
<td>65</td>
<td>73</td>
<td>81</td>
<td>90</td>
<td>98</td>
<td>106</td>
<td>114</td>
</tr>
</tbody>
</table>

| Ceiling height, $H$, m                  |    |    |    |    |    |    |    |    |    |
| 2.44                                    | 91 | 107| 122| 138| 154| 169| 185| 200| 216|
| 2.74                                    | 82 | 96 | 110| 124| 138| 152| 166| 180| 194|
| 3.05                                    | 75 | 87 | 100| 113| 126| 138| 151| 164| 177|
| 3.35                                    | 68 | 80 | 92 | 104| 115| 127| 139| 150| 162|
| 3.66                                    | 63 | 74 | 85 | 96 | 106| 117| 128| 139| 149|
| 3.96                                    | 59 | 69 | 79 | 89 | 99 | 109| 119| 129| 139|
| 4.27                                    | 55 | 64 | 73 | 83 | 92 | 102| 111| 120| 130|
| 4.57                                    | 51 | 60 | 69 | 78 | 86 | 95 | 104| 113| 121|
| 4.88                                    | 48 | 57 | 65 | 73 | 81 | 90 | 98 | 106| 114|

Minimum area of sound-absorbing material as a percentage of the floor area

<table>
<thead>
<tr>
<th>Sound absorption coefficient, $\alpha_1$</th>
<th>0.45</th>
<th>0.50</th>
<th>0.55</th>
<th>0.60</th>
<th>0.65</th>
<th>0.70</th>
<th>0.75</th>
<th>0.80</th>
<th>0.85</th>
<th>0.90</th>
<th>0.95</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling height, $H$, ft</td>
<td>91</td>
<td>82</td>
<td>75</td>
<td>68</td>
<td>63</td>
<td>59</td>
<td>55</td>
<td>51</td>
<td>48</td>
<td>46</td>
<td>43</td>
<td>41</td>
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<tr>
<td>[continued...]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE** — Sound absorption coefficients stated by a manufacturer to be greater than 1.0 based on laboratory tests may be taken as equal to 1.00 for purposes of this annex.

Source: Peggy (2003)
CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This Chapter describes the approach employed in conducting the research. This includes the study design, study site, study population, inclusion and exclusion criteria, sampling design and sampling techniques, research tools, data management plan, and data analyses.

3.2 STUDY DESIGN

Barratt & Mirwan (2009) defined cross-sectional study as a design in which data is gathered on a given population at particular time to study the relationship between diseases or other health related conditions, and other variables of interest. In this study, acoustics characteristic data of 28 classrooms in 7 public schools in Accra were collected at a given time to assess the hearing health of pupils. A descriptive cross-sectional design was therefore adopted for this study.

3.3 STUDY SITES

The study was conducted using 28 classrooms of 7 primary and junior high schools in the Greater Accra Region. These schools were selected based on their construction features such as treated acoustical rooms, windows, doors, location (near automobile traffic, market area, construction site, football parks, sea side). This encompassed various classroom conditions experienced in the schools.

3.4 SAMPLE SIZE CALCULATION

The sample size of the schools was calculated using a critical score (Z) of 90% confidence interval (1.64), and an allowable error margin (E) of error margin of 0.1, and 0.5 proportion of and 0.5 proportion of schools. Assuming these values in the equation below, a minimum sample
size of 28 classrooms was generated. Based on this calculation, 28 classrooms from seven selected schools in Accra were used for the study.

3.5 STUDY POPULATION

The study population comprised 7 selected schools in the Greater Accra Region: three from Ga East District, two from Ga West District and two from Accra Metro.

3.6 INCLUSION AND EXCLUSION CRITERIA

3.6.1 Inclusion Criteria

- Acoustically untreated classrooms in the study sites
- Classrooms with open windows and doors bare floors, and high ceilings
- Classrooms located near automobile traffic, markets, playgrounds, airplane traffic, construction sites, and the sea side

3.6.2 Exclusion Criteria

Schools with classrooms in the study sites that were acoustically treated and located away from noise sources were exempted from the study.

3.7 SAMPLE AND SAMPLING TECHNIQUE

The sample population consisted of 4 selected classrooms in each school to provide an overview of the classroom conditions. Purposive sampling and simple random technique were adopted for the study. Lavrakas (2008) defined purposive sampling as “a judgmental or expert sample”, and the main objective is to produce a sample to be used to assume the representation of the population. The schools were purposively sampled because the study required specific
characteristics such as noisy environment, while simple random sampling via balloting was used for selection of classrooms. According to Gravetter & Forzano (2011), this technique gives each member of a given population an equal chance to be chosen as part of the sample to avoid bias.

3.9 RESEARCH TOOLS AND METHODS

3.9.1 Sound Level Meter

A sound level meter (SLM) was used to measure background noise or sound levels. The values of the acoustics measurement are displayed as shown in Fig 3.1.

![Figure 3.1: Block diagram of SLM](source: www.slideserve.com)

The Cirrus Research plc type 2 sound level meter (model number CR: 161B) was used to assess:

- **Background noise in the classrooms (occupied and unoccupied)**. Measurements were recorded at the centre of the students’ sitting place for 10 minutes continuously to minimise possible changes in acoustics conditions. Occupied classroom noise measurements were determined during teaching periods whilst unoccupied classroom noise measurements were obtained in the same classrooms when schools were on vacation.
• **Equivalent sound pressure level:** This was measured while activities were on-going in the schools and classrooms. Data was collected for 30 minutes in each classroom. The SLM was placed 1.3 m from the ground and 1 m away from the walls. The readings were taken at the middle and the back of the classroom near the window since it was considered the noisiest place of the classroom. The evaluation was based on ANSI S12.60 (American National Standards Institute (ANSI), 2010).

• **Time-weighted average (TWA):** This is the time (hours) student spent in the classroom during the day was determined using an occupational noise calculator (Noisemeters Inc, n.d). The maximum intensity levels and hours spent in the classroom were used for the calculations.

### 3.9.2 Reverberation Time

Reverberation time is used to assess the volume of reverberation in space and the required time for the level of a steady sound to decay by 60 dB after the sound has ceased. The time of sound decay depends on the amount of absorption of sounds in a room, the geometry of the room and the sound frequency. RT is expressed in seconds. This decay is normally measured over the first 10, 20 or 30 dB and then extrapolated to the full 60 dB range. The RT frequency dependent of a room is normally given for the center of a third octave band frequency filter of 500 Hz or 1 kHz or a frequency dependent response curve of the RT of the frequency, (Tontechnik-Rechner-Sengpielaudio, 2017).
3.9.3 Measuring Equipment

- Balloons: These were popped at different positions in the classroom.
- Recording equipment: This was placed in the middle of the classroom to record the sounds produced from popping the balloons.
- Microphone: This was positioned about 1 m from reflective surfaces including the floor. The microphone should be far enough away from the balloon to avoid the effect of direct sound (International Organization for Standardization, 2008) as indicated in the requirement of ISO 3382-2 (2008). Data from this measurement was analyzed using the Room EQ Wizard software as shown in Fig 3.2.

![Figure 3.2: Main room view](http://ugspace.ug.edu.gh)
3.10 SIGNAL-TO-NOISE RATIO

Signal-noise ratio was evaluated by subtracting the signal level of the teacher’s voice and occupied background noise level in the classroom. The signal level of the teacher’s voice was established by measuring about 0.91m distance from the teacher. This was compared with the level of sounds to the inverse square law which states that the intensity of sound diminished by 6 dB when the distance of the source is doubled.

3.11 DATA MANAGEMENT PLAN

Codes were assigned to the selected schools and kept confidentially. Data collected was kept in a folder on a laptop and protected with a password.

3.12 DATA ANALYSIS

Data analysis was done by using the IBM Statistical package for social scientist (SPSS) version 22. The outcome was presented using frequency, means and standard deviations and presented with tables. The mean noise levels, RT and SNR were compared with international standards using one sample t-test at 95% confidence level.

3.13 ETHICAL CONSIDERATIONS

Ethical clearance was sought from the Ethics and Protocol Review Committee of the school of Biomedical and Allied Health Sciences and Ministry of Education. Consent was also sought from the selected schools to assess the background noise, RT and SNR in the classrooms.

3.14 DISSEMINATION OF RESULTS

The outcome of the research will be submitted as a Master of Science degree in Audiology to the University of Ghana, College of Health Sciences and the Department of Audiology, Speech and Language Therapy, School of Biomedical and Allied Health Sciences, the Ministry of Education.
and the library. The findings of the study which are of scientific and technical value will be published in international peer reviewed journals.
CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

This study aimed to analyze the acoustic characteristics of classrooms and to compare the findings with ASHA and ANSI standards. The results presented in this Chapter include demographic distribution, background noise in occupied and unoccupied classrooms, RT and SNR in the sampled classrooms.

4.2 DEMOGRAPHIC DISTRIBUTION

Twenty-eight classrooms with opened windows and doors from 7 public schools in the Greater Accra region were sampled for this study. The ages of pupils ranged between 4 and 18 years. Student enrollment per class ranged from 64 to 97 pupils. The least teacher-to-pupil/student distance recorded was 5.4 m whiles the furthest distance was 32.9 m as presented in Table 4.1.

Table 4.1: Average teacher-to-student distance

<table>
<thead>
<tr>
<th>School</th>
<th>Teacher-to-student distance (m)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nearest</td>
<td>Furthest</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>5.4</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>5.4</td>
<td>37.4</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>4.5</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>5.4</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>6.8</td>
<td>32.9</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>5.4</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>6.0</td>
<td>34.0</td>
<td></td>
</tr>
</tbody>
</table>
4.3 BACKGROUND NOISE IN UNOCCUPIED AND OCCUPIED CLASSROOMS

Tables 4.2 depict the average minimum and maximum background noise levels recorded in both unoccupied and occupied classrooms in all 7 schools. The level of noise in unoccupied classrooms ranged from 40.7 to 54.1 dBA (mean = 47.54 ± 3.72 dBA) whereas that of occupied classrooms ranged from 57.1 to 75.2 dBA (mean = 65.02 ± 5.2 dBA).

Table 4.2: Average noise level in unoccupied and occupied classrooms

<table>
<thead>
<tr>
<th>School</th>
<th>Unoccupied classroom noise levels (dBA)</th>
<th>Occupied classroom noise levels (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>A</td>
<td>42.00</td>
<td>51.20</td>
</tr>
<tr>
<td>B</td>
<td>46.20</td>
<td>51.10</td>
</tr>
<tr>
<td>C</td>
<td>42.00</td>
<td>51.60</td>
</tr>
<tr>
<td>D</td>
<td>44.00</td>
<td>54.10</td>
</tr>
<tr>
<td>E</td>
<td>42.00</td>
<td>50.10</td>
</tr>
<tr>
<td>F</td>
<td>40.70</td>
<td>46.20</td>
</tr>
<tr>
<td>G</td>
<td>44.80</td>
<td>50.10</td>
</tr>
</tbody>
</table>

4.4 EQUIVALENT SOUND PRESSURE LEVEL

The Leq is the level of sound that constitutes the amount of energy over a given time. That is, it is a period of mean SPL in a given environment and expressed in dBA (American National Standards Institute, 2010). The evaluation was based on ANSI S12.60 (ANSI), 2010). Time-weighted average (TWA) that is, the hours student spent in the classroom during the day, was determined using an occupational noise calculator (Noisemeters. Inc, n.d.). The maximum intensities and hours spent in the classroom were used for the calculations. The minimum and
maximum Leq recorded were 50.1 dBA and 99.7 dBA respectively (mean = 87.6 ± 12.16 dBA).

The average minimum and maximum Leq for each school are presented in Table 4.3

Table 4.3: Average noise exposure limits per hour

<table>
<thead>
<tr>
<th>School</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50.10</td>
<td>96.00</td>
</tr>
<tr>
<td>B</td>
<td>91.50</td>
<td>97.80</td>
</tr>
<tr>
<td>C</td>
<td>50.10</td>
<td>96.70</td>
</tr>
<tr>
<td>D</td>
<td>82.50</td>
<td>99.70</td>
</tr>
<tr>
<td>E</td>
<td>83.60</td>
<td>96.60</td>
</tr>
<tr>
<td>F</td>
<td>80.80</td>
<td>95.30</td>
</tr>
<tr>
<td>G</td>
<td>84.60</td>
<td>96.30</td>
</tr>
</tbody>
</table>

4.5 REVERBERATION TIME

The RT was measured across 500, 1000 and 2000 Hz frequency band using the impulsive noise method and ranged from 0.65s to 0.9s (mean = 0.77 ± 0.07s). The average RT of each school is shown in Table 4.4, Fig 4.1 and Fig 4.2. The time taken for the sound to decay by 30dB (T_{30}) was measured and extrapolated to T_{60} as required by the protocol.
Table 4.4: Reverberation time

<table>
<thead>
<tr>
<th>School</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.65</td>
<td>0.88</td>
</tr>
<tr>
<td>B</td>
<td>0.65</td>
<td>0.82</td>
</tr>
<tr>
<td>C</td>
<td>0.74</td>
<td>0.90</td>
</tr>
<tr>
<td>D</td>
<td>0.68</td>
<td>0.87</td>
</tr>
<tr>
<td>E</td>
<td>0.70</td>
<td>0.84</td>
</tr>
<tr>
<td>F</td>
<td>0.70</td>
<td>0.81</td>
</tr>
<tr>
<td>G</td>
<td>0.77</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Figure 4.1: Lowest reverberation time
Signal-noise-ratios were evaluated by subtracting the signal level of the teacher’s voice and occupied background noise level in the classroom. The recorded SNRs ranged from 3.6 to 10.5 dBA (mean = 7.17± 2.12 dBA). The average SNR results are shown in Table 4.5.

**Table 4.5: Signal-to-noise ratio**

<table>
<thead>
<tr>
<th>School</th>
<th>Signal-to-noise ratio (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>A</td>
<td>3.60</td>
</tr>
<tr>
<td>B</td>
<td>4.00</td>
</tr>
<tr>
<td>C</td>
<td>3.80</td>
</tr>
<tr>
<td>D</td>
<td>3.70</td>
</tr>
<tr>
<td>E</td>
<td>5.00</td>
</tr>
<tr>
<td>F</td>
<td>6.20</td>
</tr>
<tr>
<td>G</td>
<td>4.50</td>
</tr>
</tbody>
</table>
4.7 INTERNATIONAL STANDARDS, THE REALITY, AND THE DISCREPANCY

Table 4.6 presents a comparison of ASHA and ANSI guidelines for classroom acoustic components and the findings of this study. One sample t-test was conducted to determine the statistical difference.

Table 4.6: International standards, the reality, and discrepancy.

<table>
<thead>
<tr>
<th>Acoustic components</th>
<th>International standard</th>
<th>Research finding</th>
<th>$t_{(27)}$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background noise</td>
<td>ASHA: 35</td>
<td>ANSI: 35</td>
<td>47.53</td>
<td>17.83</td>
</tr>
<tr>
<td>(unoccupied room)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dBA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT (s)</td>
<td>≤ 0.4</td>
<td>≤ 0.6 (small classroom)</td>
<td>0.77</td>
<td>27.66 (ASHA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.77 (ANSI)</td>
</tr>
<tr>
<td>SNR (dBA)</td>
<td>≥ +15</td>
<td>Not addressed</td>
<td>+7</td>
<td>-19.54</td>
</tr>
</tbody>
</table>

It can be observed that the unoccupied classroom background noise level, as well as RT recorded in this study, were significantly higher than the recommended levels by ASHA and ANSI whereas SNR was much lower ($p < 0.05$).
CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

This study aimed to analyze the acoustic characteristics of selected classrooms in Ghana and to compare with the standards set by ANSI and ASHA. Poor classroom acoustics can have negative effects on children learning activities. A total of 28 classrooms were randomly selected from seven schools. In each school, measurement of background noise in occupied and unoccupied classroom, RT, SNR, distance from the teacher to the students and time-weighted average were calculated.

5.2 BACKGROUND NOISE

The enrolment of children in each classroom was between 64 and 97. The ages of the children in the classroom were between 4 and 18 years. Noise in the classroom appeared to be generated by external source and the children depending on the particular activity that was being carried out. The mean noise level in unoccupied classrooms was 47.54 dBA which is significantly higher ($p < 0.05$) than the recommended 35 dBA by ANSI and ASHA. This represents a 35.8% deviation. This supports the first hypothesis ($H_1$) of this study.

However, similar trends have been observed by other authors in the literature. In Brazil, Guidini et al. (2012) recorded a mean of 46.08 dBA from a sample of 10 unoccupied classrooms. Owojori, Gadzama, and Sow (2017) compared noise levels in 9 unoccupied primary school classrooms and 11 unoccupied secondary school classrooms in Zaria - Kaduna State, Nigeria. A mean of 54.04 dBA was recorded among the primary school classrooms whiles 49.93 dBA was recorded among secondary school classrooms. The difference was however not significant ($p =$
0.34). The extreme levels observed in the literature include 62.2 dBA by Sundaravadhanan, Selvarajan and McPherson (2017) among 23 unoccupied classrooms of 4 primary schools in Southern India and 65 dBA by Knecht et al, (2002) among 32 unoccupied classrooms in 8 public schools in Central Ohio (USA).

The mean noise level in occupied classrooms in this study was 65.02 dBA. This is significantly higher \( t_{(27)} = 15.26, p < 0.05 \) than the recommended 50 dBA according to Rosenberg et al. (1999). This is however comparable to the findings of Chan et al. (2015) (68.17 dBA) in 146 occupied classrooms in Hong Kong. Also, Shield, Greenland, and Dockrell (2010) reported mean levels of 53 to 72 dBA from a review of twelve studies in Europe and North America.

The high level of noise can be attributed to sitting of schools close to major roads and markets and inadequate acoustic treatment of classrooms. With the mean noise level being higher than the standard, it implies the classrooms assessed in this study do not provide the ideal acoustic environment for teaching and learning.

5.3 STUDENTS’ NOISE EXPOSURE LIMITS PER HOURS IN THE CLASSROOM

In this study, the mean noise exposure level was 87.6 dBA. This is even higher than the recommended noise exposure limit of 85 dBA by NIOSH and OSHA for industrial settings (NIOSH, 1998; OSHA, 2013). Noise level beyond 85 dBA is capable of causing physiological damage. This implies that the students and teachers may be liable some of these damages besides the difficulty the students will face understanding spoken language in the presence of the background noise.
5.4 REVERBERATION TIME

Results from reverberation time in all the classrooms were greater than (mean = 0.77, $p < 0.05$) recommended standard (0.6s) which is the ideal value for classrooms (American National Standards Institute, 2010). This supports the second hypothesis ($H_2$) for this study. In a similar study by Klatte et al. (2010), RT was 0.69s to 0.92s in 5 classrooms from 2 schools. Another study by Persson, Kristiansen, Lund, Shibuya, & Nielsen, (2013) revealed that teachers whose classrooms had RT above the standard reported much discomfort to classroom noise than other noises when compared with the average classroom noise and short RT. In a research by Zannin, Ferreira, & Sant’Ana (2009) measured RT between 0.6 to 1.1s. These results are similar to that of this study.

The presence of high RT makes it difficult to differentiate sounds and understand spoken language since syllables will overlap and affect concentration and speech intelligibility. This will eventually affect the teaching and learning process (Klatte, Hellbrück, Seidel, & Leistner, 2010; Department of Education and Skills, 2013).

5.5 SIGNAL-TO-NOISE RATIO

With regards to SNR, a mean of 7.17 dBA was recorded in the current study. This is significantly lower ($p < 0.05$) than the recommended +15 dBA. Hence, this supports the third hypothesis ($H_3$). This is consistent with the findings of other authors in literature who recorded SNR between -7 to 8.39 dBA (Arnold & Canning, 1999; Crandell & Smaldino, 1995, 2000; Chan et al, 2015). Below +15 dB SNR, the level of background noise about the same as the teachers’ voice which will make it difficult for children will to hear and understand teachers during lessons. Research by Neuman, Wroblewski, Hajicek, & Rubinstein (2010) discovered that young children needed better SNR in more reverberant classrooms. Young children need higher SNR since they have
limited working memory capacity and low speech intelligibility compared to young adults (Massie, Theodoros, McPherson, & Smaldino, 2004). Low SNR will require high listening effort that will also require greater cognitive performance which is associated with decrease performance on the secondary activity (Howard, Munro, & Plack, 2010).

On the other hand, teachers will be forced to raise their voice over the background noise in order to be heard. A study by Guidini et al (2012) reported a significant correlation between the intensity of teachers’ voice and classroom background noise. This can result in various forms of vocal disorders. In that particular study, 90% of the teachers were found to have a vocal strain. This explains why poor classroom acoustics is a problem especially when it is combined with factors such as impaired hearing (Massie, Theodoros, McPherson, and Smaldino, 2004) and learning in a non-first language (Mayo, Florentine, & Buus, 1997). The result indicates that there is a need to maximize SNR in the classrooms.
CHAPTER SIX

CONCLUSION, RECOMMENDATION AND LIMITATION

6.1 SUMMARY

This Chapter presents the summary of the study, conclusion and recommendations. This study aimed to analyze the acoustics characteristics of classroom and to compare with the standards set by ANSI and ASHA.

The study was conducted in the Greater Accra Region using twenty-eight classrooms of seven selected schools. In each classroom, background noise in occupied and unoccupied classrooms, reverberation time, SNR were measured. The average background noise in occupied classroom was 65 dBA and unoccupied classroom was 47.5 dBA, the average Leq was 87.6 dBA. The average SNR was +7 dBA and the average reverberation time was 0.77 seconds.

6.2 CONCLUSION

In all, none of the classrooms assessed in this study met the acceptable international standards for classroom acoustic situation for teaching and learning activities. This implies that the classrooms assessed in this study do not have the ideal acoustic situation which directly influences speech intelligibility of student and increases teacher fatigue, stress and increases the chances of them developing voice problems.

6.3 RECOMMENDATION

The following recommendations were devised to meet the acceptable international standards, these strategies include:
• In the allocation of new schools, sources of noise both within and outside of the school should be considered. There should be some distance in the allocation of schools example away from a market place and road traffic noise.

• Modification of existing classrooms to provide better sound absorption examples having an acoustic ceiling, carpet on the floor to decrease noise from footfall and dragging of furniture which will reduce reverberation, SNR and background noise especially in unit schools of the hearing impaired.

• Activities in the schools that will cause noise should be rescheduled outside school hours

• Teachers unions, special education professionals, Parent Teachers Association (PTA), the stakeholders should engage in the efforts to improve acoustics in the classroom.

• Provision for amplification in the schools should be made. To achieve a suitable SNR signal sounds should be amplified. Frequency modulation (FM) system can be used to achieve a good SNR.

6.4 LIMITATION

The first limitation of this study was the inability to assess the effect of increased signal-to-noise ratio and background noise on the students’ academic performance. The second limitation was also the inability to seek the teachers’ perception of the effect of the increased signal-to-noise and background ratio on daily teaching activities.
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APPENDIX I

SAMPLE OF LETTER TO RESEARCH SITES

UNIVERSITY OF GHANA
DEPARTMENT OF AUDIOLOGY, SPEECH
AND LANGUAGE THERAPY
SCHOOL OF BIOMEDICAL AND ALLIED HEALTH SCIENCES

Ref. No.: ……………………………
17th May, 2018

The Headmaster/Headmistress
Madina No. 3 JHS
P.O. Box MD 1468
Madina, Accra

Dear Sir/Madam,

INTRODUCTION OF MSc RESEARCH STUDENT, Ms. CATHERINE SENYASU

The Department of Audiology, Speech and Language Therapy of the University of Ghana School of Biomedical and Allied Health Sciences (UG-SBAHS), Korle Bu presents its compliments to the Headmaster/Headmistress of Madina No. 3 JHS

Ms. Catherine Senyasu (10955657), a final year MSc Audiology student of the Department of Audiology, Speech and Language Therapy of UG-SBAHS is carrying out a research study entitled “CLASSROOM ACOUSTICS IN GHANA: THE CASE OF SEVEN SELECTED SCHOOLS IN ACCRA” under the supervision of Dr. Y.N. Otete (Audiologist), and Dr. S. Anim-Sampson (Physicist). The UG-SBAHS Ethics and Protocol Review Committee has approved her research proposal as meeting all ethical and protocol requirements.

The Madina No. 3 JHS has been chosen as a suitable study site for this important research study which will be conducted during the period May to June 2018.

In this regard, the Department humbly requests your kind permission to allow her perform her research studies in your School. Your earnest and kind consideration would be greatly appreciated. Thank you.

Yours sincerely,

[Signature]
Dr. S. ANIM-SAMPOONG
(Acting Head of Department)

DEPARTMENT OF AUDIOLOGY
SPEECH & LANGUAGE THERAPY
SCHOOL OF BIOMEDICAL AND ALLIED HEALTH SCIENCES

P.O. Box KB 143, Korle Bu, Accra, Ghana
Website: www.sba.h.ug.edu.gh

University of Ghana http://ugspace.ug.edu.gh
APPENDIX

ETHICAL CLEARANCE

Ref. No.: ………………………………

Ms. Catherine Senyasu,
Dept. of Audiology, Speech and Language Therapy,
SBAHS,
Korle Bu.

Dear Ms. Senyasu,

ETHICS CLEARANCE


Following a meeting of the Ethics and Protocol Review Committee of the School of Biomedical and Allied Health Sciences held on Tuesday 30th January, 2018, I write on behalf of the Committee to approve your research proposal as follows:

TITLE OF RESEARCH PROPOSAL: CLASSROOM ACOUSTICS IN GHANA: THE CASE OF SEVEN SELECTED SCHOOLS IN GREATER ACCRA REGION, GHANA

This approval requires that you submit three-monthly review reports of the protocol to the Committee and a final full review to the Committee on completion of the research. The Committee may observe the procedures and records of the research during and after implementation.

Please note that any significant modification of the research must be submitted to the Committee for review and approval before its implementation.

You are required to report all serious adverse events related to this research to the Committee within seven (7) days verbally and fourteen (14) days in writing.

As part of the review process, it is the Committee’s duty to review the ethical aspects of any manuscript that may be produced from this research. You will therefore, be required to furnish the Committee with any manuscript for publication.

This reviewed report is valid till 31st August, 2018.

Please always quote the ethical identification number in all future correspondence in relation to this protocol.

Thank you.

Yours sincerely,

Dr. S. D. Amanquah
(Chairman, Ethics and Protocol Review Committee)

Cc: Dean
   School Administrator
   Head, Dept. of Audiology, Speech and Language Therapy

COLLEGE OF HEALTH SCIENCES

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