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Classroom acoustics and intervention strategies to enhance the learning environment

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CLASSROOM ACOUSTICS AND INTERVENTION STRATEGIES

TO ENHANCE THE LEARNING ENVIRONMENT

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ABSTRACT

The classroom environment can be an acoustically difficult atmosphere for students to learn effectively, sometimes due in part to poor acoustical properties. Noise and reverberation have a substantial influence on room acoustics and subsequently intelligibility of speech. The American Speech-Language-Hearing Association (ASHA, 1995) developed minimal standards for noise and reverberation in a classroom for the purpose of providing an adequate listening environment. A lack of adherence to these standards may have undesirable consequences, which may lead to poor academic performance.

The purpose of this capstone project is to develop a protocol to measure the acoustical properties of reverberation time and noise levels in elementary classrooms and present the educators with strategies to improve the learning environment. Noise level and reverberation will be measured and recorded in seven, unoccupied third grade classrooms in Lincoln Parish in North Louisiana. The recordings will occur at six specific distances in the classroom to simulate teacher and student positions. The recordings will be compared to the American Speech-Language-Hearing Association standards for noise and reverberation. If discrepancies are observed, the primary investigator will serve as an auditory consultant for the school and educators to recommend remediation and intervention strategies to improve these acoustical properties. The hypothesis of the study is that the classroom acoustical properties of

noise and reverberation will exceed the American Speech-Language-Hearing Association standards; therefore, the auditory consultant will provide strategies to improve those acoustical properties.

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CHAPTER 1

INTRODUCTION, REVIEW OF LITERATURE, AND STATEMENT OF THE PROBLEM

Introduction

Spoken language is a critical component for learning in the classroom. The majority of activities in classrooms require students to listen and engage in spoken communication. Therefore, it is essential that existing standards for classroom acoustics be used. Noise in a classroom may arise from external sources which are sounds originating outside the school building (e.g., street traffic, construction). Noise may also come from internal sources which are sounds originating inside the school building but not in the classroom (e.g., ventilation, heating systems, adjacent classrooms). Or noise may come from within the classroom (e.g., talking, desk movements).

Reverberation is one indirect source of internal noise. Simply defined, reverberation is the persistence of sound, an echo. It results from room surfaces that reflect sound waves which create an overlapping of the sound waves and results in noise. Reverberation is detrimental to speech understanding in the absence of other forms of internal or external noise.

External and internal sources of noise can be controlled to a large extent through the implementation of architectural designs in new classrooms and modifications of existing ones. Overall noise level and reverberation are two prevalent factors that affect speech understanding in the classroom. Controlling for these two acoustical factors can significantly improve a student's signal-to-noise ratio and thus, speech understanding. Signal-to-noise ratio is the mathematical difference, in decibels, between the loudness of the presenter's voice and the loudness of the background noise. If the speaker's voice is louder than the background noise, the signal-to-noise ratio is a positive number. The greater the signal-to-noise ratio, the more speech intelligibility improves. Extensive literature has been published by researchers in various disciplines (e.g., acousticians, audiologists, architects, educators, etc.) about the history of architectural acoustics from standards to remediation for inadequate structures and the benefit of acoustically sound structures (Taylor, 1980; ASHA, 1995; Crandell & Smaldino, 1999; Pekkarinen & Viljanen, 1990).

Compliance with minimal standards of the American Speech-Language-Hearing Association (1995) for acoustics should be the goal for every educational classroom. Proper control of noise and reverberation in the classroom improves understanding of speech which can positively influence academic performance. Noncompliance with these standards may result in poorer speech understanding with detrimental effects on academic performance. The purpose of this capstone project is to develop a protocol to determine if reverberation time and overall noise levels occurring in elementary classrooms in north Louisiana meet the minimum standards of the American Speech-Language-Hearing Association. A secondary purpose is to develop strategies for consideration in changing the classrooms to meet the existing standards.

Review of Literature

The Classroom Acoustical Environment

In an educational setting, the noise levels in an unoccupied classroom vary from 41 to 51 dB (Manlove, Frank & Vernon-Feagans, 2001; Bess, Sinclair, & Riggs, 1984; Crandell & Smaldino, 1994). According to Crandell and Smaldino (1995), the noise levels in an occupied classroom are on the average, 10 dB greater (52 to 62 dB SPL) than when unoccupied. This increase is attributed to the talking and movement of children and teachers and the shuffling of desks, books and book bags. The variables that increase the noise levels in an occupied classroom are numerous (e.g., number of students, age of students, activities performed in classroom, etc.) However, noise levels that are a result of external and internal factors in an unoccupied classroom can be managed, if not controlled, through architectural design and modifications.

Noise levels in a classroom reduce the signal-to-noise level. The result is greater effort is required by the student to understand. In addition, speech understanding is reduced. For normal hearing children, the preferred signal-to-noise ratio is between +15 to +20 dB (Houtgast, 1981; Bradley, 1986; Manlove, Frank, & Vernon-Feagans, 2001; Nelson, Soli, & Seltz, 2002). However, in a typical classroom, the signal-to-noise ratio has been shown to vary from -7 to +5 dB. The reported discrepancy between ideal and actual SNRs would suggest architectural designs that do not address, or are woefully inadequate in abating, external and internal noise (Bess, Sinclair, & Riggs, 1984; Blair, 1977; Crum & Matkin, 1976; Finitzo-Hieber & Tillman, 1978).

Reverberation is one common source of internal noise. Reverberation is not traditionally thought of as a source of internal noise but it nonetheless affects classroom communication by decreasing speech understanding. Crandell and Smaldino (2001) defined reverberation as "the persistence of sound within an enclosed space when sound waves reflect off of hard surfaces" (p. 4). The influence of reverberation in a room is measured by time. Reverberation time is reported in seconds (s), with shorter reverberation times being preferred to longer ones. The American Speech-Language-Hearing Association (1995) reported that reverberation times within unoccupied classrooms can range from 0.4 to 1.2 seconds, with a mean of 0.7 seconds. Knecht, Nelson, Whitelaw and Feth (2002) suggested 0.4 seconds as a reverberation time appropriate for the classroom.

The quality of these acoustical parameters, noise level and reverberation times, is crucial for proper speech understanding. Noncompliance with minimal standards of quality for noise level (unoccupied room) and reverberation time is detrimental to a child's ability to process, learn, and excel academically. A poor acoustical environment has been shown to academically impede the learner; the overall impact is on a student's ability to learn novel information (Pekkarinen & Viljanen, 1990; Crandell & Smaldino, 2000).

A child's ability to aurally perceive a message along with his or her capacity to discriminate speech and language will be negatively impacted by elevated noise and prolonged reverberation time. A breakdown in the message conveyed to the student, resulting from noise and reverberation, may result in a lack of substantial information needed for speech understanding. This breakdown occurs when noise completely or partially masks portions of speech. This typically occurs in the form of low frequency, high energy noise masking higher frequency, lower energy consonants. Since young students do not have the same language and learning experiences as adults, they have limited ability to interpret new information masked by noise. Their ability to "fill in" missing auditory information is inefficient due to limited linguistic experiences, lexicon, and central auditory maturity. Hence, the need for adherence to the standards of the American Speech-Language-Hearing Association (1995) for acceptable noise levels and reverberation in classroom environments. The architectural design of a classroom determines its' acoustical characteristics and ability to control for noise.

The Link between the Ear and the Brain

The communication link between the ear and brain activates when a person enters a room. It begins with the bilateral peripheral and central auditory system collecting speech information and coding it for intensity, frequency, and temporal qualities. This information is almost simultaneously interpreted and "stored" by the auditory processing centers of the brain subconsciously. In a normal hearing listener, subtle differences in intensity, frequency, and timing are analyzed for the purposes of determining the location and distance of the speaker, size of the room, and ease of intelligibility. This information is adapted by the brain to maximize understanding.

When noise and reverberation are encountered, the central auditory system in the brain can recognize reflection intervals within a few milliseconds. While standing in a room with moderate acoustical damping, a conversation can be held without difficulty even though the walls may be reflecting every syllable with various time delays. Taylor (1980) described the operation of the systems as follows:

> If you receive a series of almost identical sounds in rapid succession over a small time interval, the chances are that there is only *one* sound and so you must register the sensation as though it is only one sound; but you must store away the information about these time delays for future reference (p. 146).

In other words, if a series of similar sounds such as /pa/ and /ba/ are presented into a room at a fast rate with minimal time delay between each presentation of sound, the listener is most likely to perceive only one sound. Schow and Nerbonne (1996) attributed this to the temporal resolution ability of the central auditory system, which is the ability to quickly and precisely arrange the auditory information. When there is normal hearing, temporal processing abilities vary among listeners and age is the predominate variable.

Excessive reverberation and noise degrade speech intelligibility for all students, regardless of age. This result may be poorer academic performance. Acoustics should be a key priority in the design of all classrooms. Even in the absence of noise outside the classroom and noise created within the classroom, a listener's speech understanding will decline significantly as the distance between the listener and the speaker increases. Increased reverberation times magnify external and internal noise, and a difficult listening environment is created.

Acceptable noise levels and reverberation time in the classroom are even more crucial for younger students because they are not experienced with or skilled at understanding speech in noise. The contributing factors are limited linguistic experience, limited lexical inventory, and an immature central auditory system, specifically the corpus callosum.

The corpus callosum is the portion of the brain that connects the two cerebral hemispheres. Neuman and Hochberg (1983) described it as a tract of connective fibers that allows sharing of information between the right and left hemisphere. The corpus callosum does not mature until approximately 13 years of age. Prior to the maturation, right ear dominance will be observed for dichotic listening tasks. In other words, competing acoustic stimuli between the ears, such as speech and background noise or speech and speech, cannot be processed efficiently. Some portions of the speech signal will be lost resulting in broken speech or undecipherable speech for the young listener. In view of limited linguistic experience and lexicons, the younger student is poorly suited to "fill in" the missing portions of speech.

It should also be noted that younger students are likely to experience more middle ear infections than older students or adults. These infections often result in temporary conductive hearing losses. Nelson, Soli, and Seltz (2002) pointed out that this temporary hearing loss greatly magnifies the hearing difficulties associated with noise and reverberation time. The impact of middle ear infections and conductive hearing loss on academic performance are beyond the scope of the present study. However, prevalence of these conditions in younger populations is significant and should be considered when discussing the importance of classroom acoustics.

Noise

Background noise in the classroom can come from many sources at varied intensity levels. Crandell and Smaldino (2000) defined background noise as "any undesired auditory stimuli that interferes with what a child wants, or needs to hear and understand" (p. 363). The background noise in a classroom interferes with the teacher's message by masking, either partially or completely, speech cues making speech difficult to understand. Specifically, consonant sounds are easily masked by background noise. According to Katz (1994), consonants have less spectral energy than vowels and the audibility of consonants is reduced or eliminated by background noise. Speech intelligibility can be significantly reduced even if the audibility of consonants is only partially masked because understanding of speech is heavily influenced by the presence of consonants.

Classroom noise can be produced either from inside or outside the classroom. The average noise levels for occupied classrooms, according to Bess (1999), are 55 to 60 dB, which exceed recommended listening levels. The signal-to-noise ratio is a quantitative measure often used to determine the likelihood of speech intelligibility. To improve the signal-to-noise ratio, the noise level within the classroom is typically the greatest obstacle. There are two options for reducing noise levels that exceed recommended standards: noise abatement which eliminates or reduces the unwanted noise or decrease the distance between the speaker and listener(s).

For ideal classrooms, Bess recommended that the distance between the students and teacher should not exceed six to eight feet. This distance limits the amount of background noise and surface reflections that may interfere with the communication process. However, this distance may not be feasible since classroom dimensions and the number of students may require a greater distance from teacher to student in order to accommodate a seat for every student in a traditional column/row style seating arrangement. Therefore, nontraditional, more creative seating arrangements may be considered. For example, the children may sit on carpet in close proximity to one another and the teacher when possible.

Reverberation

Reverberation has been and remains a dilemma for architectural acousticians and designers. The acoustical impact of reverberation is measured in time. Katz (1994) identified reverberation time as the time required for the sound pressure level to decrease by 60 dB after the sound source stops (Katz, 1994). According to Studebaker and Hochberg (1993), reverberation time differs with frequency; the duration is longer for the lower frequencies, relatively unchanged from 500 to 2000 Hz, and shorter for higher frequencies. Simply stated, reverberation is an echo in which the reflection of sound results in the overlapping of sound waves which reduces speech intelligibility. The magnitude of the reduction of speech depends largely on the length of the echo which is the reverberation time.

Mitchinson (2001) provided a history of room acoustics which dates back to 1895 when Wallace Sabine, a Harvard physicist, pioneered the science of architectural acoustics. At that time, the new Fogg Art Museum at Harvard received many complaints from professors and students about its poor acoustics. Sabine identified the source of the poor acoustics as a reverberation problem. Sabine examined the room and experimented with reverberation by placing different amounts of cushions and carpets, and numbers of students in the room. From his investigations, he described a way to calculate reverberation, which he stated that "reverberation time rises in direct proportion to a room's cubic volume and in inverse proportion to the amount of sound-absorbing material" (p. 62). According to Mitchinson, Sabine's calculations provided researchers and architects a basis for measuring reverberation time.

According to Taylor (1980), reverberation time is the most essential objective measurement of room acoustics. In the past, reverberation time was measured by shooting a pistol on the stage and recording the discharge with microphones at different locations in the hall. Taylor reported that the recordings were played through octave band-filters that enabled the reverberation time to be measured at various frequency ranges. If the reverberation times were unacceptable (i.e., greater than 1.5 seconds in a large room), absorbent materials and/or the locations of reflective surfaces would be added or adjusted accordingly.

Reverberation and Noise

The detrimental effect of lengthy reverberation time in a classroom and on speech intelligibility have been discussed. In a manner similar to noise, consonants are affected by reverberation. The energy of the vowel sounds are lengthened by reverberation which results in the masking of the consonants that follow, usually in the final position. Crandell and Smaldino (2000) suggested that since vowels contain more overall energy and length than consonants, the masking of consonants by reverberant vowels happens quite often. To avoid this consonant masking, suitable reverberation times have been identified but will vary depending on room size. For smaller classrooms 0.4 seconds is an ideal reverberation time and for larger classrooms, between 0.6 and 0.8 seconds is recommended (Bess, 1999).

Although size is a significant variable affecting reverberation, the materials used in room construction have as much, if not more of a significant effect on reverberation. The cost of materials and durability is a significant factor to consider for any building or rooms. Classrooms have traditionally been constructed with concrete, concrete block, brick, and hard tile. Although less expensive than other building materials, these are highly reflective and therefore highly reverberant. More often than not, reducing reverberation time requires the refitting of a classroom with sound absorbing materials. The type and amount of sound absorbing material to be used depends on a number of factors. Regardless, all sound proofing material will be rated by its ability to absorb sound, known as the absorption coefficient. Before a room can be acoustically treated with absorbing materials, accurate measurements of the acoustical properties, reverberation time and noise, should be taken.

Measuring Reverberation

Reverberation determines the quality of the acoustic signal as well as the intelligibility of that signal. Determining reverberation time is an essential measure for improving room acoustics. Two methods for determining reverberation time are the complex formula calculations as pioneered by Sabine or use of a sound level meter capable of measuring and recording reverberation time (Crandell and Smaldino, 1999). The latter is more efficient and accurate.

According to Crandell and Smaldino (1999), measuring reverberation time using a sound level meter requires the presentation of a broad-band stimulus (white noise) at a high intensity (intensity level not disclosed) into an unoccupied room. A high intensity broad-band signal is used because the intensity level has to decrease by 60 dB in order to measure reverberation. A sound level meter that is capable of measuring reverberation time is used and records the time it takes the sound to decrease by 60 dB at different frequencies. Crandell and Smaldino reported that reverberation time is typically recorded at 500 Hertz (Hz) to 2000 Hz since the majority of speech energy is present at these distinct frequencies.

However, in the absence of a sound level meter capable of measuring and recording reverberation time, it can be estimated using a formula. The reverberation formula pioneered by Sabine is as follows: $RT(60) = 0.05V/(\Sigma S\alpha)$ where V is the volume of the room (ft^3), S is the surface area (ft^2), α is the absorption coefficients of materials and Σ is the sum of S times α for all surfaces of the room (Seep, Glosemeyer, Hulce, Linn, & Aytar, 2000). The room volume, surface area of all room materials, and the absorption coefficients for the materials must be identified to use this formula. This can be a tedious and time consuming task and results in only an estimate of reverberation time.

Regardless, volume is determined by measuring and multiplying the length, width, and height of the classroom. The volume is then multiplied by the constant 0.05, which results in the numerator. The area of the classroom walls, ceiling, and floor is calculated to obtain the denominator. The area of the floor and ceiling is determined by multiplying the length and width; whereas, the area of the walls can be calculated by multiplying the length of each wall by the height. Next, the absorption coefficients of all surface materials must be determined (Crandell and Smaldino, 1999). This represents the most tedious and time consuming portion of reverberation time estimation.

According to Seep, et al (2000) absorption coefficients are the amounts of sound energy that will be absorbed, with an assigned rating ranging from 0.00 to 1.0. Since absorption coefficients are measured in specific laboratories, absorption coefficient tables are generally referenced for coefficients of common materials located in a classroom. Each wall, ceiling, and floor surface area will then be multiplied by the coefficient of the material that covers that specific area and added to obtain the total absorption value of the room. Lastly, the numerator will be divided by the denominator resulting in the estimated reverberation time of the classroom. These identical steps are then completed for all frequencies to be measured.

Regardless of the measuring method, reverberation time is measured when the room is unoccupied, because people, along with their clothing, may absorb some of the sound present in the room. For complete accuracy, reverberation time should be calculated for all octave bands since reverberation times vary at different frequencies. An octave is a "doubling or halving of frequency, for example, 250 Hz is one octave above 125 Hz, 500 Hz is one octave above 250 Hz, and 500 Hz is two octaves above 125 Hz" (Speaks, 1999, p. 165). However, for an approximate calculation, reverberation time may be measured at one octave band that represents a frequency where speech occurs (i.e., 1000 Hz).

Effects of Reverberation

Pekkarinen and Viljanen (1990) investigated the effect of reverberant acoustic treatment on speech understanding in two rooms used in an educational setting, a classroom and larger multipurpose hall. Both rooms were tested prior to and following the addition of mineral wool panels in the classroom and prefabricated boards containing mineral wool in the multipurpose hall. Additionally, reverberation times were measured and recorded for both rooms, pre-and post-reverberation treatment. The experimental stimuli used in the experiment were sentences, words, and nonsense words presented both in quiet and in noise (broadband) at various signal-to-noise ratios. The intensity levels of the experimental stimuli were presented at the most comfortable level for both the classroom and multipurpose hall. A large number of listeners were used to better illustrate real world results (classroom n = 152, multipurpose hall n = 193).

Following acoustical treatment for reverberation, Pekkarinen and Viljanen reduced the reverberation time by 1 second in the classroom and 0.5 seconds in the multipurpose hall. Varying levels of improvement were seen for speech understanding both in the classroom and in the multipurpose hall for quiet and in noise. Because of the large numbers of listeners participating in the study, Pekkarinen and Viljanen suggested that there was a large degree of variance for improvement of speech understanding observed among the responses. However, significant distinct trends were observed for the experimental conditions (classroom and multipurpose hall, pre and post treatment) and stimuli (sentences, words, and nonsense words in quiet and noise). In general, Pekkarinen and Viljanen found that the acoustical treatment for reverberation was significant for reverberation time and improvement of speech understanding for all conditions and groups with greater improvement observed for the speech in noise conditions.

Pekkarinen and Viljanen reported the following conclusions. First, the acoustic refitting improved speech discrimination in both types of rooms. In quiet, the effect of acoustic refitting on discrimination was slight or not significant; however, the effect of acoustic refitting was well observed in noisy environments. Second, variability increased as the signal-to-noise ratio increased and it was approximately the same before and after the acoustic refitting of the rooms. Finally, the interaction of reverberation and noise was highly significant for all the speech discrimination tests.

In a similar study, Neuman and Hochberg (1983) examined 25 normal hearing children's understanding of speech in reverberation. The children were assigned to groups of five as a function of age, which ranged from 5 to 13 years. Their performance was compared to five normal hearing adults. One of Neuman and Hochberg's goals was to determine if a child's ability to understand speech in reverberant situations identical to those in a classroom would vary as the child matured. The experimental speech stimuli consisted of vowel-consonant-vowel nonsense syllables recorded by a male which were played and recorded in an empty room. Also, the recording of the stimuli consisted of reverberation times (0.4 seconds and 0.6 seconds) which were produced by varying absorbent fiberglass panels in the empty room.

Neuman and Hochberg used a sound-treated booth with the stimuli delivered through headphones binaurally at 60 dB SPL, and monaurally at 63 dB SPL to all listeners. By testing each child individually in the sound controlled room, greater control of the testing environment and stimuli was afforded. This isolated the age group as the main variable. The results revealed that as reverberation time increased, the identification of the nonsense syllables decreased for each age group. It was also observed that as the ages of the children increased, so did their performance. Additionally, Neuman and Hochberg found that binaural scores were superior to monaural scores but performance was not significantly different between monaural and binaural conditions for the 13 year-old age group. The authors interpreted this as representation of the maturation of the corpus callosum. The performance of the 13 year-olds for monaural versus binaural was essentially equal; these results also were found in the adult group.

Neuman and Hochberg's findings demonstrated as age increases, the ability to understand speech in reverberant environments increases (0.4 seconds and 0.6 seconds) and asymptotes around 13 years of age. Additionally, their conclusions supported the benefit/need for short reverberation times of 0.4 seconds or lower for children in order to maximize their abilities to understand speech.

To provide greater isolation of reverberation and age as a function of speech understanding, Finitzo-Hieber and Tillman (1978) evaluated the monosyllabic word discrimination ability of children (eight years eight months to twelve years eight months) in an anechoic chamber. In addition to being sound treated, an anechoic chamber is completely void of reverberation (reverberation time of 0.0). By conducting the experiment in an anechoic chamber, the researchers ensured that reverberation was completely controlled.

Finitzo-Hieber and Tillman created reverberation times of 0.0 seconds, 0.4 seconds, and 1.2 seconds in 50 monosyllabic words by installing various amounts of fiberglass insulation panels in an empty classroom. The monosyllabic words were recorded in competition with speech babble. The primary signal and competing speech babble were presented to the children at signal-to-noise ratios of 0 dB, +6 dB, +12 dB and $+\infty$ (absent competing message) and at the previously defined reverberation times. The children were seated 12 feet from the loudspeaker which is the relative distance of a child sitting in a classroom while the teacher lectures.

Finitzo-Hieber and Tillman also found that increased reverberation significantly reduced word discrimination ability in quiet, and even more so with competition. Once again, the significant effect of increased reverberation times and noise on a child's ability to understand speech was demonstrated. In addition to a reverberation time of no more than 0.4 seconds, the authors recommended that the signal-to-noise ratio be no less than +6 dB.

More recently, Knecht, Nelson, Whitelaw and Feth (2002) evaluated the effects of reverberation and noise in educational settings by measuring and recording the classroom acoustical properties of reverberation time and noise, in eight public school buildings (32 classrooms). Their goal was to determine if the classrooms met the standards of the American Speech-Language-Hearing Association (1995) and the American National Standards Institute (2002), and secondly, to determine whether a checklist could be created to help educational administrators and teachers determine the levels of noise and reverberation time.

The classrooms were selected at random but of the 32 classrooms, 12 were located in new suburban schools, 12 were in old urban schools, and eight were in rural schools. For every classroom, identical procedures were used to record the measurements. First, the height, length, and width were measured and room volume was determined. Next, measurements of noise and reverberation time were obtained at five locations clearly identified on the floor.

First, noise levels were measured at five locations marked on the floor. Noise readings were taken with the examiner outside the room, initiating the noise recording by a remote feature with the sound level meter, which had a 10 second delay, held in position by a tripod. After noise readings had been recorded from the five locations, reverberation time was measured and recorded from each. The reverberation time measurements were also recorded with a remote function while the examiner was absent from the room.

To generate the white noise necessary for reverberation time measurements, a speaker, amplifier, and compact disc player were positioned in the front corner of the room, on the floor facing up. Knecht, et al. determined that this was the best position to produce an omnidirectional signal. Reverberation times were recorded for 500, 1000, and 2000 Hz. Knecht and his colleagues used a checklist to examine the internal and external noise conditions, such as heating, ventilating, and with the air conditioning system off or on, during the measurements.

Knecht et al. found that the noise level recordings varied from 34.4 dBA to 65.9 dBA for the 32 classrooms. Only four classrooms had noise levels lower than 35 dBA. The lowest recorded noise level was 30 dBA, which is the American Speech-Language-Hearing Association's (1995) recommended noise standard. In other words, of the 32 classrooms measured, only one met the ASHA classroom standard for noise. Of the remaining 31 classrooms, the background noise levels were five to fifteen dBA greater than the ASHA standard. Knecht et al. (2002) also reported the effect of the ventilation system, when on, on internal noise. With the system on, the mean noise levels increased to 49.7 dBA as compared to 39.8 dBA with the system off. The reverberation time recordings for the 32 classrooms revealed that only six classrooms met the ASHA (1995) standard of 0.4 seconds. In general, smaller rooms had shorter reverberation times, whereas, the larger rooms and rooms with high ceilings had longer reverberation times.

Knecht, Nelson, Whitelaw and Feth's (2002) second goal, to establish a checklist capable of identifying rooms which would exceed noise and reverberation time compliance, was not successful. The data revealed no significant correlation between the amount of criteria met and the calculated noise and reverberation times. Knecht et al. therefore determined that a checklist was not a reliable tool for estimating noise levels and reverberation times. The authors pointed out that the classrooms with the lowest reverberation times and noise levels were located in one of the new schools in the suburban district.

Knecht et al. revealed that the majority of the noise levels and reverberation times exceeded the recommended American Speech-Language-Hearing Association (1995) standards. If these findings are representative of classrooms across the nation, it would suggest that the majority of classrooms are insufficient listening environments.

The Role of Classroom Acoustics

Through casual observation, it is apparent that architectural structures differ substantially by design. Taylor (1980) discussed some basic considerations for an architect to address in the process of planning and designing a structure. One consideration is the elimination of unwanted sounds from a building or room. The complete elimination of external noise is rarely feasible; therefore, the goal is to make unwanted sounds as quiet as possible. It is of equal importance to design for the equal dispersion of speech energy throughout the room. Taylor stated that an important consideration for achieving this goal is the number of people who are to be in the room. The larger the area to be covered, the harder it is to spread the acoustical energy evenly without the assistance of an amplification system. Lastly, when these considerations have been addressed and thought to be met, the reverberant qualities of the room are to be considered and adjusted accordingly.

Speech energy and how it is distributed is the primary consideration when planning and designing a room with regards to reverberation. According to Taylor, conversational speech occurring during quiet and carried from a distance of one meter averages approximately 40 dB sound pressure level in relation to the reference intensity of 10^{-12} watts/meter ^{2}. Within a room, there may be surfaces that have a 100% reflection coefficient, so that even the smallest sound will be reflected until it dissipates. As speech intensity is increased, the original speech signal will overlap because of the reflections resulting in reduced speech understanding. This resulting echo will degrade speech by distorting both the spectral and temporal qualities of the original speech signal.

Recommended Standards for Classroom Acoustics

According to the American Speech-Language-Hearing Association (1995), the background noise level of an unoccupied classroom should not exceed 30 dBA and the reverberation time should not exceed 0.4 seconds. The ideal signal-to-noise ratio for a classroom environment is +15 dB. The American National Standards Institute (2002) recommended that the background noise source not exceed 35 dBA and that the reverberation time be within 0.6 seconds (i.e., classroom of 10,000 cubic feet or less) to 0.7 seconds (classrooms ranging between 10,000 and 20,000 cubic feet).

The Basics of Classroom Acoustical Design and Materials

General concepts and considerations of damping must be taken into account by architects who design lecture theatres, concert halls, etc. for the purposes of communication. Damping is the dissipation of sound energy as it leaves the source (Seep, Glosemeyer, Hulce, Linn, & Aytar, 2000). A compromise must be reached between the size of the room (how far and how loud does speech need to be for good understanding) and the damping qualities of the room to eliminate time delays and reverberation of speech. Essentially, the speech energy must be absorbed at some rate along its path to the listener. The rate and amount of absorption is dependent on the size of the room and the number of listeners in that room.

To ensure high-quality acoustical properties necessary for good speech understanding, extensive delays should be prevented and the images of the source should be gathered near the original source. In other words, the listener should perceive the source of the speech signal to be at its actual location and the time delay between the source and the listener should reflect an accurate distance. Bess (1999) suggested that, when possible, designing low ceilings with adequate reflective properties can generate beneficial sound reinforcement without extensive time delays. However, where larger numbers of listeners will gather and, to eliminate a feeling of enclosure, high ceilings are typically constructed. The consequence is that high ceilings produce long time delays and echoes. To address this common problem, irregular surfaces of sound absorbing materials can be used to absorb unwanted reflections and disperse the speech signal in an even manner.

Design alone cannot always be expected to achieve appropriate acoustical responses for noise and reverberation. As previously mentioned, the selection and placement of various sound absorbing and displacing materials are often used to create an acoustically pleasing environment where speech is easily heard and understood. The materials used in such an effort will have specific acoustical properties, such as absorption, reflection and dispersion, all of whose frequency range of audible sounds differ. These materials will have certain filtering characteristics and their selection will be based on the particular type and amount of noise to be treated (Crandell & Smaldino, 1999). In other words, these materials have the capability to absorb certain types and amounts of sound, as well as obstruct or allow other sounds to pass through.

Traditional classrooms have been designed in a square or rectangle arrangement with hard tile or concrete floors, high ceilings and cinderblock walls. It is also common to find that one of the walls is partially composed of windows which are adjacent to an outdoor playground. The result is a highly reverberant communication environment and one that allows excessive external noise due to the reflective nature of these hard surfaces and the poor attenuation qualities of the windows. The design of these classrooms and selection of construction materials is typically, if not entirely, based on cost.

Classroom Acoustical Treatment

Reverberation, a significant contributing factor to internal noise, can be improved with sound absorbing materials. Soft permeable materials such as fabrics, clothing and air absorb sound. "In general, the greater the porosity (absorbency) of a given volume of material, the greater its sound absorbing capabilities" (Warnock, 1980, p.3). Depending on the mounting method of sound absorbing sheet material, the absorption coefficients (the extent to which a material can absorb energy) may differ. Warnock suggested that:

> increasing the thickness increases the absorption at all frequencies unless the absorption coefficient is already close to 1.0; increasing the air gap between the sheet and a solid backing surface increases the absorption at the low frequencies; and covering the sound absorbing material with a very lightweight sheet of plastic or a protective layer more than 10 percent open reduces the absorption coefficients slightly at the higher frequencies only (p. 4).

To further improve reverberation, materials used for absorbing sound are typically constructed in patches or strips of material. Crandell and Smaldino (1999) recommended adjusting the shape, configuration, and mounting method of these materials to improve reverberation. Many sound absorbing materials, called absorbers, are preassembled and have been tested for absorbency. These preassembled materials are tested in anechoic or reverberation chambers which are sound enclosures void of reverberation or outside noise. Since the absorption coefficients measured will vary according to the dimensions and volume of the patches and the distances in between them, it is important to refer to the manufacturers' test reports to establish the proper installation coefficients.

The degree to which understanding of speech will be improved by adding sound absorbing material will vary depending on the type, amount, and mounting system used. The cost of the sound absorbing material will vary depending on these three variables. Despite the known detrimental effects to speech understanding and ultimately, academic success, more often than not cost is the prohibitive factor in sound treating classrooms.

Absorption Coefficients

When a traveling sound wave encounters an object, the sound wave will undergo some degree of absorption, reflection and/or dispersion (Seep, Glosemeyer, Hulce, Linn, & Aytar, 2000). A combination of these events can occur simultaneously. The absorption of sound offers the greatest reduction of reduction time. Therefore, materials that absorb sound are used in either the construction or refitting of a room to create the best possible communication environment. However, not all sound absorbing materials are of equal value. The degree to which sound is absorbed is identified by an absorption coefficient. The absorption coefficients (α) of materials determine the amount of sound that will be absorbed and thus, reduce reverberation.

However, just as all sound absorbing materials are not equal, neither do they absorb all frequencies in the same manner. High frequency sounds are more easily absorbed than low frequency sounds. Therefore, more choices of material are available for high frequency sounds. Low frequency sounds are more difficult to absorb and their sound waves are more likely to be reflected. As presented by Seep et al., (2000), Table 1 represents the absorption coefficients for materials, by frequency, often used in educational settings.

Table 1. Absorption coefficients of classroom materials

	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Glass fiber ceiling tile	0.70	0.85	0.75	0.85	0.90	0.90
Fiberglass wall panel-2 inches thick	0.30	0.50	0.80	0.90	0.80	0.75
Concrete block-painted	0.10	0.05	0.06	0.07	0.09	0.08
Gypsum wall board	0.25	0.15	0.08	0.06	0.04	0.04
Plaster wall or ceiling	0.14	0.10	0.06	0.05	0.04	0.03
Linoleum or tile floor	0.02	0.03	0.03	0.03	0.03	0.02
Thin carpet on concrete	0.05	0.10	0.25	0.30	0.35	0.40
Wood door	0.15	0.11	0.09	0.07	0.06	0.06
Glass	0.35	0.25	0.18	0.12	0.07	0.04
Chalkboard	0.01	0.01	0.01	0.01	0.02	0.02

The number designated as the absorption coefficient denotes the fraction of sound energy (not dB intensity level) the material will absorb at that certain frequency (ranging in decimals from zero to one) and occurs in anechoic chambers. Materials with absorption coefficients of 0.20 or greater are considered sound absorbent materials (Katz, 1994).

Proper Acoustical Treatment for a Classroom

Bess (1999) emphasized that there are proper design and construction methods to be used with constructing or refitting classrooms. Materials should have an elevated mass per unit square area and the walls should be doubled with airspaces in between them. According to Bess, double paned windows should be used because they reduce noise by 17 dB or greater depending on the amount of space between the panes. This attenuation of noise can greatly affect the signal-to-noise ratio with the classroom.

Fourcin et al. (1980) provided possible solutions for noise abatement such as increasing the distance between the teaching area and the noise source. The addition of barriers between the noise source and the teaching area, such as storage rooms, corridors, and libraries, can be used. Corridors or hallways can be carpeted, the legs of desks and chairs can be wrapped with felt if carpeting is not an option, and draperies or curtains can be used to absorb sound. Also, chalkboards can be secured to the walls and acoustical tile can be hung from the ceiling or on the walls to aid in sound attenuation. Constructors and educators should consider these recommendations when building or renovating classroom facilities.

Reducing External Classroom Noise

Controlling external noise is usually considered during the initial design of a school building. According to Crandell and Smaldino (1999), alleviating outside noises begins with the architectural plan and materials to be used in construction of the building. Initially, the location of the school building should be considered so that it is built away from noise sources such as heavy traffic areas, railroads, airports, and construction areas. In order to achieve this, consultations should be arranged with contractors, school officials, architects, audiologists, and teachers.

The materials used in construction should be considered to minimize external noise. Crandell and Smaldino (1999) recommended using a seven-inch concrete wall to attenuate outside noise by 53 dB. However, the addition of traditional single pane windows and wood panel doors in that wall will reduce its attenuation properties by 20 to

24 dB. Consequently, Crandell and Smaldino recommended that the external wall contain double pane windows and sound absorbent doors. External walls can also be enhanced by installing absorptive materials, such as fiberglass, between the studs of the wall, or inserting many layers of gypsum or plywood boards between the walls.

For school buildings already erected, windows can be replaced or sealed with non-hardening caulk to increase attenuation. The addition of shrubs or trees outside the windows and earthen banks around the buildings can increase attenuation of noise before it reaches inside the classroom. Reducing external noise can be accomplished in many ways and the goal is to absorb or reduce noise before it enters the classroom.

Reducing Internal Classroom Noise

Many of the same methods for reducing external noise are used to reduce internal noise. Fourcin et al. (1980) recommended increasing the distance between the teaching area and the noise source to allow for a reduction of noise in relation to distance (e.g., the further away from the noise source, the lower the intensity of the noise). Also, barriers could be included between the noise source and the teaching area such as storage rooms, corridors, and libraries. Classrooms should not be located next to high noise sources, for example, the gymnasium, cafeteria, and/or band room. Similar to the exterior wall construction, the interior walls that align noise sources (i.e., hallways or adjacent classrooms) should be built with additional absorptive materials, such as gypsum or plywood boards between wall studs as well as sealing wall cracks. Crandell and Smaldino (1999) suggested installing acoustical ceiling tile in the classroom since the absorbing qualities of the tile will reduce noise. Carpeting in the hallways can reduce the noise caused by foot traffic on tile or cement floors. The doors should be acoustically treated or fit with rubber seals and should not contain air ducts which lead to the hallway or outside. To reduce noise from the adjacent classrooms, the back of wall-mounted blackboards can be lined with absorptive materials.

Carpeting should also be installed in the classroom. Thick, wall-to-wall, padded carpet can reduce noise generated by movements of desks, chairs, and shoes. Thick curtains can be hung to help impede noise in the room. Rubber tips can be placed on the legs of desks and chairs if the room is not carpeted. The walls and ceiling should be covered with acoustical paneling to absorb unwanted sounds. According to Katz (1994), the ceiling is the ideal place to install absorbing materials because of its size. A large amount of absorbent materials can be placed on the ceiling which, because it is relatively unreachable, will prevent damage to the materials. There is evidence that installation of acoustical materials in classrooms improves speech intelligibility (Finitzo-Hieber & Tillman, 1978; Pekkarinen & Viljanen, 1990).

The acoustics of a room are dependent on noise, reverberation times, and absorption coefficients of materials within. Modifications to a classroom alone may not solve the issue of inadequate acoustics; strategies for communication can also assist in improving the communication environment.

Strategies to Improve Classroom Communication

Communication strategies, in addition to or sometimes in the place of acoustical modifications, can improve the understanding of speech. There are recommended communication strategies for use by teachers. The teacher should face the students when speaking so his or her mouth is visible and speech is directed to the children. This allows for visual reinforcement of acoustic stimuli. The rate and intensity of the teacher's speech is critical. The teacher's speech should be clear and spoken at a slightly reduced rate and at a higher intensity. The distance between the teacher and children should be reduced when possible so that the teacher's voice is at an advantageous intensity level.

As reported by Schow and Nerbonne (1996), the maximum distance for effective speechreading is five feet and decreases considerably at 20 feet. A short distance is preferred because a child will be able to visualize the teacher's mouth and the speech will be at an appropriate intensity level. An increased distance from teacher to child may result in decreased visibility and speech intensity. The teacher should also rephrase difficult material to provide additional opportunities for the students to understand the information. If a student asks a question or presents a statement to the class, the teacher should repeat what the student said to give all of the other students an opportunity to hear the information.

Statement of the Problem

Classrooms are an environment in which children listen to and learn novel information. In the majority of classrooms, this learning process is accomplished auditorily; therefore, the acoustics of the classroom are important. The American Speech-Language-Hearing Association (1995) developed acoustical standards to ensure that classrooms are adequate for understanding speech. The acoustical properties of noise and reverberation are the two predominate factors that influence speech understanding and therefore are of the greatest concern.

However, investigations have revealed that the majority of classrooms do not meet these minimal standards. The lack of compliance with these standards may ultimately result in poorer academic performance for students in those classrooms.

Students below the age of 13 years are at particular risk for poor academic performance due to their limited lexical experiences, lexicon, and immature central auditory system.

The purpose of this capstone study is to develop a protocol to determine if the acoustic properties of noise and reverberation in seven elementary classrooms in north Louisiana meet the minimum American Speech-Language-Hearing Association standards (1995). A second purpose of the study is to provide recommendations to improve the acoustics for those classrooms that do not meet the minimal standards.

The primary experimenter will gather detailed measurements of the classrooms including the dimensions, acoustical characteristics of noise and reverberation occurring within seven, unoccupied third grade elementary classrooms located in Lincoln Parish in North Louisiana. Once the primary investigator obtains the room measurements and descriptions of surface materials, the noise level and reverberation time will be compared to the American Speech-Language-Hearing Association standards on classroom acoustics. If discrepancies are observed, the primary investigator will serve as an auditory consultant for the school and educators to recommend remediation and intervention strategies to enhance the classroom acoustics. The hypothesis of the study is that the acoustics of the elementary classrooms will not meet the American Speech-Language-Hearing Association standards; therefore, the auditory consultant will provide strategies to improve the classroom acoustics.

CHAPTER 2

PROTOCOL FOR MEASURING CLASSROOM ACOUSTICS

Poor classroom acoustics are a problem which affects speech intelligibility for children and ultimately learning. Therefore, inadequate acoustics can have a major influence on a child's academic development. The protocol for the experimental measures to be used in this study is designed to provide a foundation for future research on classroom acoustics, specifically noise and reverberation. Measuring the noise and reverberation of a classroom is a multi-step procedure that will be defined in detail.

Effects of Classroom Acoustics on Speech

Reverberation times and noise levels will be measured in seven, third grade elementary classrooms in public schools in Lincoln Parish in north Louisiana. Third grade elementary classrooms were chosen as opposed to middle school or high school due to the fact that research has revealed students (below age 13) are most at risk for poor speech understanding since young students do not possess the same language and auditory processing skills as adolescents or adults (Neuman & Hochberg, 1983; Pekkarinen & Viljanen, 1990; Crandell & Smaldino, 2000; Bess, 1999; Manlove, Frank, & Vernon-Feagans, 2001). According to Neuman and Hochberg (1983), as a child gets older, the ability to fill in missing portions of speech due to masking and understand reverberant speech increases and asymptotes by 13 years of age when a child's speech communication skills mimics the ability of adults due to the maturation of the corpus callosum.

Neuman and Hochberg evaluated children's ability to understand speech in reverberant conditions to determine if speech understanding varied as a function of age. Neuman and Hochberg found that as reverberation time increased the identification of nonsense syllable decreased and as the ages of the children increased, so did their performance. These findings support the concept that short reverberation times are essential for young children to enhance their speech understanding abilities.

Two acoustical factors, noise and reverberation, will be evaluated in each of the seven classrooms. Reverberation has been identified as having a detrimental effect on the acoustical qualities of a room (Mitchinson, 2001). Poor classroom acoustics are the result of noise and reverberation time that exceed recommended standards. This results in a communication environment where speech is not easily understood (Nelson, Soli & Seltz, 2002).

Noise Levels

In the present study, noise level will be evaluated in seven classrooms in the Lincoln Parish school system. According to the American Speech-Language-Hearing Association (1995), it is recommended that the background noise level of an unoccupied classroom not surpass 30 dBA. However, measurements routinely identify noise levels in unoccupied classrooms that vary from 41 to 51 dB (Manlove, Frank & Vernon-Feagans, 2001; Bess, Sinclair, & Riggs, 1984; Crandell & Smaldino, 1994). Crandell and Smaldino (1995) reported even greater levels of overall noise and found noise levels within an occupied classroom to be on average, 10 dB greater than previously reported.

A plausible explanation for this 10 dB increase is the occupancy of the students and the teacher, shuffling of desks and books, and oral communication in the classroom. These noise levels are not likely isolated incidents; rather, it is more probable that they reflect common acoustical characteristics in the typical classroom.

Reverberation Time

In the present study, reverberation time will be evaluated in seven classrooms in the Lincoln Parish school system. The American Speech-Language-Hearing Association (1995) recommended that the reverberation times of an unoccupied classroom not exceed 0.4s. According to the American National Standards Institute (2002), speech intelligibility begins to be impacted when reverberation time exceed 0.4 seconds. However, measurements routinely yield reverberation times within unoccupied classrooms that reach 1.2 seconds (Knecht, Nelson, Whitelaw, & Feth, 2002). Knecht et al. evaluated the reverberation times and overall noise levels in elementary classrooms by measuring the acoustical properties in unoccupied classrooms with a sound level meter and high intensity, broad-band white noise stimuli. The results revealed that the majority of the classrooms failed to meet the American-Speech-Language-Hearing Association (1995) and the American National Standards Institute standards (2002) for reverberation time and overall noise levels. Inadequate reverberation times reduce a child's ability to understand speech. Finitzo-Hieber and Tillman (1978) also found a negative association between reverberation time and speech understanding.

Experimental Measurements

Evaluating and measuring the acoustical properties of a room can be a complex procedure. This is because acoustical properties of the classroom environment are constantly changing with the presence or absence of students. For this reason, the measurements of reverberation time and noise level will be obtained when the room is unoccupied (Crandell & Smaldino, 1999; Knecht, Nelson, Whitelaw, & Feth, 2002). There will be no children or teacher in the classroom and their personal belongings, such as backpacks and coats will have been removed. The primary investigator will record the measurements by remote function and will not be present in the classroom. The classroom will contain all the furniture and wall accessories that are present during a school day when occupied by the children and teacher.

Experimental Instrumentation

Measuring noise and reverberation time requires sophisticated recording instrumentation such as a Class I Sound Level Meter capable of measuring reverberation and a stringent protocol to ensure accurate measurements that are consistent among and between the classrooms. The instrumentation and protocol to be used are based on the study of Knecht et al. (2002) in which the investigators assessed noise levels and reverberation time in unoccupied elementary classrooms.

The volume of each room will be calculated by measuring the length, width, and height. The acoustical measurements will be obtained throughout the classroom at five specially designated locations on the floor to ensure they are void of potential standing wave patterns. The investigator will place the amplifier and speaker in the front, left corner of the room with the speaker on the floor facing up to represent an omni-directional signal. The primary investigator, absent from the room, will take all measurements by remote function. At each of the five points, reverberation time and overall noise level will be measured. The reverberation time is to be measured at 500, 1000, and 2000 Hz since these are the frequencies essential for understanding speech.

Noise and reverberation for the present study will be measured using a Bruel and Kjaer 2239-A Integrating Sound Level Meter. This is a Class I sound level meter commonly used to record environmental and occupational-health related noise. This specific sound level meter makes peak measurements with the option of independent frequency weightings, A, B or C as well as specific octave band recordings. Therefore, the sound level meter is capable of averaging the signal which produces a recording representative of the maximum intensity level of the signal, as well as measuring at specific frequencies and octave bands.

The sound level meter is designed to be held at arms length or supported by a tripod and contains a microphone, microphone preamplifier, filters for frequency weighting, time averaging circuits, and dB SPL display (Decker & Carrell, 2004). The sound level meter microphone detects the sound and the diaphragm converts the sound into electrical voltages. The amplitude of the sound is then presented on the display in dB SPL for a specific frequency weighting, such as A, B, or C. For the present study, measurements will be recorded using the A-weighted scale because it closely resembles the sensitivity of human hearing (Knecht, Nelson, Whitelaw, & Feth, 2002).

A one-half inch random incidence condenser microphone with fast, slow, and impulse time weightings will be used. Various microphones are available for sound level recordings. According to Decker and Carrell (2004), the two most common sizes are one-inch and one-half inch although larger sizes are available. The advantage of the smaller microphones is that they are able to detect higher sound pressure level measurements. Microphones are of three classes: random incidence, free field, and pressure.

Random incidence microphones are used for measurements in the sound field, where sound will arrive from various directions, such as a lecture hall. Free field microphones are used in environments that are absent of reflection, such as an open field. Pressure microphones are used for calibrations of audiometer earphones (Decker & Carrell, 2004). For this study, a one-half random incidence microphone will be used because sound in a classroom may be reflected in various directions.

The stimuli to measure reverberation time will be 20 minutes of white noise which will be generated with a Kay Elemetrics Computerized Speech Lab, Model 4150 and recorded on a Sony compact disc. The Computerized Speech Lab is an acoustic analysis system available for speech and voice analysis, and measurement and therapy. This instrumentation will be used because it is capable of generating a continuous white noise signal which can be recorded on an external compact disc recorder. According to Crandell and Smaldino (1999), reverberation is measured by introducing a broad-band signal, usually white or pink noise, at a high intensity and recording it using a sound level meter. The intensity level of the standard signal (white noise) will be presented at a calibrated reference intensity level of 70 dB SPL (Finitzo-Hieber & Tillman, 1978). An EV Dynacord 7100 amplifier will be used to amplify the stimulus to 70 dB SPL for free-field presentation. The stimuli will be delivered through a Radio Shack Realistic speaker. The sound level meter will be calibrated by the primary investigator before and after each classroom measurement using a Bruel and Kjaer Sound Level Calibrator Type 4231.

The digital recording device, amplifier and speaker used to assess the overall noise level and reverberation time will be placed in the front left corner of each unoccupied classroom to achieve an omnidirectional sound (speaker facing up). Figure 1 represents the placement of the equipment and measurement locations to be used in the experimental procedures.

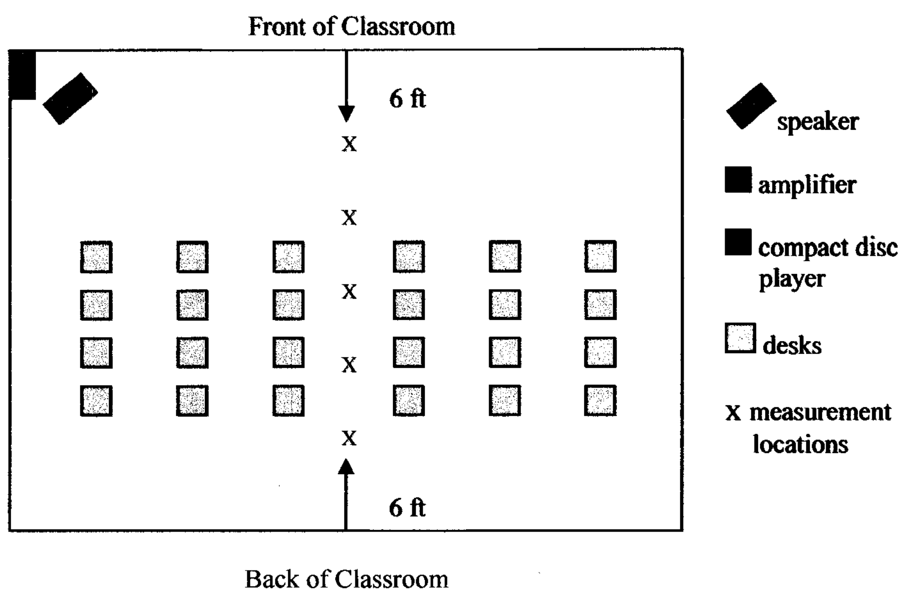

Figure 1. Classroom placement for equipment and measurement locations

The acoustical parameters of reverberation and overall noise level will be measured at five different points in each classroom. These points are six feet from the center of the front wall, six feet from the center of the back wall, the center of the classroom, the halfway point between the front six feet mark and the center of the classroom, and the halfway point between the back six feet mark and the center of the classroom. These points will be located throughout the center of each classroom and marked on the floor with tape. The sound level meter will be placed on a tripod at a height of four feet to approximate student ear level over each point to record the measurements. These distances were chosen to approximate the traditional column/row style classroom arrangement.

Measurements will be taken throughout the length of the classroom where the children normally sit in rows and will occur at different times during the school day. Noise levels and reverberation times will be assessed either before or after school and during recess or lunch break in order to have an unoccupied classroom during an average school day. The measurements at each distance will be averaged and compared to the American Speech-Language-Hearing Association standards (1995).

Classroom Modifications

After the overall noise and reverberation time have been measured and compared to the existing American Speech-Language-Hearing Association standards, if discrepancies are observed, the investigator will serve as an auditory consultant. The purpose of an auditory consultant is to provide remediation strategies to improve acoustics of the classroom. Certain structural materials and communication strategies can help increase speech intelligibility in rooms with poor acoustics.

Reporting Results to the Principals and Superintendent

The primary investigator will provide the superintendent and principals with a summary report of the results after the measurements occur. The summary report for the superintendent will include the results for overall noise levels and reverberation times for all seven schools and the number of schools not in compliance with the standards. However, the school's name will not be disclosed. For each principal, the summary report for that particular school will include the results for overall noise level and reverberation time and will indicate whether the classroom is in compliance with the standards. The report for the principals of the schools with inadequate acoustics and for the superintendent will also include communication strategies and recommendations for the addition of acoustical materials.

CHAPTER 3

METHODS AND PROCEDURES

Experimental Methods

Compliance with minimal standards for classroom acoustics is essential to provide an adequate communication environment conducive for learning. For students younger than 13 years, classroom acoustics are even more important due to their limited lexical experience and immature central auditory system by virtue of their age. However, measurements of classroom acoustics routinely reveal that the acoustical factors of noise level and reverberation time exceed existing standards. The purpose of this capstone project is to develop a protocol to assess the acoustical parameters of noise level and reverberation time in seven third grade elementary classrooms to determine if these acoustical qualities meet the recommended American Speech-Language-Hearing Association standards. The primary experimenter will serve as an auditory consultant for remediation for those classrooms that exceed those standards.

Experimental Locations

The experimental areas will consist of seven, third-grade elementary classrooms located in public schools in Lincoln Parish in north Louisiana. Classrooms at Choudrant Elementary, Cypress Springs Elementary, Glen View Elementary, Hico Elementary, Hillcrest Elementary, Ruston Elementary, and Simsboro Elementary School will be selected for use in the study. The schools were chosen based on location and convenience for obtaining the measurements.

Permission from the Lincoln Parish School Board Superintendent and the principals of the seven elementary schools will be requested prior to initiation of the experimental procedures. Appointments will be scheduled with the primary investigator, superintendent, and principals to discuss the purpose of and proposal for the study. During this appointment, the superintendent and principal will receive an informational brochure about the importance and benefits of measuring classroom acoustics (see Appendix A). Permission will be requested approximately three months before the experimental procedures are to begin to allow adequate time for the primary investigator to discuss the proposed research with each principal and third grade educator. After the initial appointment, permission will be requested for conducting the study by mailing a permission request form to the superintendent and principals. The requests for conducting the study are shown in Appendixes B and C.

After permission has been received, the primary investigator will schedule appointments with the principal and educators assigned to the classrooms to complete a tour of candidate classrooms. This is for the purpose of selecting those that are typical of normal classrooms and similar in physical volume. The principal and educators of the chosen classroom from each school will be reminded by telephone of the experimental procedure one week in advance of the appointed date and time. The teachers will have the responsibility to ensure that the classrooms are free of the students, backpacks, coats, etc. Only the contents that are in the rooms on a typical school day will be in the classrooms (e.g., desks, bulletin boards, posters, etc.).

Instrumentation

Noise levels and reverberation time will be measured with a Bruel and Kjaer 2239-A Integrating Sound Level Meter. This meter is capable of averaging the signal and produces a recording representative of the maximum intensity level of the signal as well as measuring specific frequencies and octave bands. The sound level meter will be calibrated by the primary investigator before and after use in each classroom using a Bruel and Kjaer Sound Level Calibrator Type 4231 which is easy to use and time efficient. It attaches to the microphone of the sound level meter and is capable of producing several pure tones at various levels, such as 94 to 114 dB. The sound level meter displays the sound pressure values of the sound source produced by the calibrator. If the sound pressure value for a specific frequency is incorrect, a screwdriver is used to adjust the settings until an accurate value is displayed.

A one-half inch random incidence condenser microphone will be used with the sound level meter because it is capable of measuring high sound pressure levels. The white noise to be used in calculating reverberation time will be generated by the Kay Elemetrics Computerized Speech Lab Model 4150 and recorded on a Sony compact disc. The Kay Elemetrics Comupterized Speech Lab is an acoustic analysis system capable of generating a continuous white noise stimulus that can be recorded on a external recording device, such as a Sony compact disc. The noise source will be amplified by an EV Dynacord 7100 amplifier and played through a Radio Shack Realistic speaker.

Experimental Procedures

Physical Volume

The physical volume of each classroom will be calculated by multiplying the length, width, and height of the classroom. At the time of measurement, each classroom will be void of students and the teacher and their personal belongings such as coats and backpacks. The classrooms will contain all items that are present on a regular school day, such as desks. Measurements will be obtained either before or after school, and during recess and/or lunch break, while the classrooms are absent of students and their personal belongings. The measurements of overall noise level and reverberation time should not be affected by the time of the measurements since the primary factor is the occupancy of the classroom.

The physical measurements to be obtained for each classroom will be the length, width, and height of the classroom. A standard 50-foot tape measure will be used and the dimensions will be recorded and used to calculate volume (see Appendix D). Appendix D is an overall noise level and reverberation time response form that includes a table on which the measurement of volume, noise level, and reverberation time will be recorded.

To measure the length of each classroom, five sites will be marked on the floor with duct tape through the middle of the classroom where the experimental recording instrumentation will be placed. The primary investigator will use a 50-foot tape measure to measure the first mark six feet from the center of the front wall and marked with tape. Next, the center of the classroom and six feet from the center of the back wall will be measured and marked. Last, the halfway point between the front six feet mark and the center of the classroom and halfway between the back six feet mark and center of the classroom will be measured and marked. Identical measuring procedures will be used in each of the seven classrooms (see Appendix E). Appendix E is a protocol for measuring overall noise levels and reverberation time. Room measurements will be taken in the absence of students and teachers. The primary investigator will also take an inventory of the physical properties within the classroom, such as the number of desks and windows and the type of material on the walls and ceiling, etc. This inventory is for the purpose of revealing the contents of the classroom at the time of measurements (see Appendix F).

Overall Noise Level

Noise level, the intensity level of noise occurring in a room, will be measured and recorded six feet from the center of the front and back wall as well as from the center of the classroom. Additional measurements will occur between the front six feet mark and the center of the room and the back six feet mark and the center of the room. Overall noise intensity will be measured at each distance and recorded (see Appendix D). Specific frequency weighting measurements will also be recorded at 500 Hz, 1000 Hz, and 2000 Hz from the described distances. The recorded overall noise levels will be compared to the American Speech-Language-Hearing Association standard of 30 dB or less (1995).

Reverberation Time

Reverberation time will be measured six feet from the center of the front wall as well as the back wall, the center of the classroom, halfway between the center of the room and the front six feet mark and halfway from the center of the room and the back six feet mark. Using octave band filtering, reverberation time will be recorded in seconds for 500 Hz, 1000 Hz, and 2000 Hz. These measurements will then be recorded (see

Appendix D). The recordings at each frequency will be averaged to achieve an overall reverberation time. Reverberation time measurements will be compared to the American Speech-Language-Hearing Association standard of 0.4 seconds or less.

Remediation

Classrooms that are not in compliance with the American Speech-Language-Hearing Association standards will receive remediation strategies from the primary investigator who will serve as an acoustical consultant. The consultant will meet with the educators and provide strategies and recommendations to alter the teaching environment to assist in improving the acoustical properties of the classroom. Preferential communication strategies as well as physical modifications to the classroom will be presented and discussed.

Effective Classroom Communication Strategies

Strategies to improve communication consist of reducing the majority of background noise and providing adequate lighting in the room so the children can visualize the teacher's facial cues and gestures. According to Crandell and Smaldino (1999), it is important that the teacher face students when speaking so his or her mouth is visible and the speech is directed toward the class. The teacher should speak clearly, at a slightly slower rate, and at a slightly higher intensity level. Accordingly, the teacher should not cover his or her mouth or chew gum when speaking. This interferes with the child's ability to utilize visual cues while listening.

The distance between the teacher and children is imperative because of the influence on the intensity of the teacher's voice. According to Bess (1999), the distance between the teacher and children should be minimized to ensure that the voice of the teacher is at an intensity level that can be heard by the entire class. A reduced distance results in less background noise interference because the teacher is closer to the child's ear and the child can rely on visual cues to aid in speech intelligibility.

Bess suggested that the teacher should not stand near noise sources, such as the air conditioning or heating unit, when speaking and should talk at a relatively loud but comfortable level. If possible, lessons should be taught while the students are sitting in close proximity to one another on carpet. This will help reduce the noise level and increase the intensity level of the teacher's voice. Communication strategies (see Appendix G) are one approach to enhancing classroom listening and the learning environment. The materials used to construct the school buildings also have a major influence on the acoustical parameters of a classroom.

Acoustical Considerations for Building Construction

First and foremost, school buildings should not be erected near noise sources such as airports, heavy traffic areas, construction sites, and railroads. When constructing a school building, certain materials should be used to assist in enhancing the acoustics of a classroom. Crandell and Smaldino (1999) recommended that external walls be thick, filled with absorbing materials (i.e., gypsum board), and should not have any windows. If windows are necessary, they should be double-paned and all cracks sealed with caulking. Also, planting shrubs outside the classrooms can assist in attenuating sound as it enters the classroom.

Acoustical Modifications for the Walls

Because of high external noise sources, the external walls should not contain any windows or doors if possible. The external wall can act as a barrier from external noise.

This can be accomplished by installing absorptive materials, such as fiberglass, between the studs of the wall, constructing thick concrete walls, or installing many layers of gypsum or plywood boards between the walls (Crandell & Smaldino, 1999). If windows on the exterior wall are necessary, they should be double-paned, installed properly, and remain closed when classes are in session. The interior walls that align noise sources (i.e., hallways or adjacent classrooms) should be built with additional absorptive materials, gypsum or plywood boards between wall studs and cracks should be sealed.

Crandell and Smaldino suggested that interior walls be lined with strips of absorptive materials such as heavy fabrics or acoustical paneling to reduce reverberation and noise. Placing thick curtains over the windows will also help impede the noise in the room. The absorptive strips or paneling should be installed halfway down the wall and not on walls parallel to each another. In addition, the back of wall-mounted blackboards can be lined with absorptive materials to reduce noise from adjacent classrooms.

Acoustical Modifications of the Ceiling

The ceiling of the classroom should be covered with acoustical paneling to absorb unwanted sounds. Katz (1994) maintained that the ceiling is the ideal place to install absorbing materials because of its size and the materials will be out of the reach of children. Crandell and Smaldino (1999) also suggested installing acoustical ceiling tile in the hallways to assist in reducing internal noise such as foot traffic or talking in the hallways. Acoustical ceiling helps in the reduction of overall noise and reverberation time. This, in turn, can lead to a more conducive learning environment.

Acoustical Modifications for the Floor

Carpeting should also be installed in the classroom. To reduce noise generated by the movement of desks, chairs and shoes, thick, wall-to-wall, padded carpet should be used. Thick carpet will assist in enhancement of the acoustical properties of the classroom. If carpet is not an option, Crandell and Smaldino suggested placing rubber tips on the legs of desks and chairs to help reduce the noise produced by their movement. Implementing these remediation strategies will reduce the overall noise levels and reverberation time in a classroom.

Data Analysis

After the overall noise levels and reverberation time measurements are obtained, they will be compared to the American Speech-Language-Hearing Association Standards (1995). Descriptive statistics will be used to organize and summarize the data. There are two main types of descriptive statistics, measures of central tendency, the center of the distribution of scores or mean and measures of dispersion, the range of the scores. Initially, the individual classroom measurements will be compared to the standards to determine if the classroom is in compliance with the standards. Next, the mean, or average, of overall noise level and reverberation time in all seven classrooms will be calculated. This will provide an overall average for each of the classroom measurements occurring in seven elementary classrooms in Lincoln Parish in North Louisiana.

APPENDIXES

APPENDIX A

CLASSROOM ACOUSTICS INFORMATIONAL BROCHURE

Classroom Acoustics Informational Brochure

Classroom Acoustics

In a classroom environment, children are constantly listening and learning novel information which is usually accomplished through spoken communication. Any interference during this process can affect a child's speech understanding ability. This, in turn, can have repercussions on a child's ability to excel in academics. There are two major acoustical properties that affect classroom acoustics, noise and reverberation. Noise, whether it is outside or inside the school building or classroom, or reverberation, the persistence of a sound, greatly interferes with spoken communication by masking speech. Therefore, it is imperative that classrooms are in accordance with standards for classroom acoustics to permit effective speech communication.

Noise Levels and Reverberation Time

Noise levels in an unoccupied classroom vary from 41 to 51 dB (Manlove, Frank & Vernon-Feagans, 2001). According to Crandell and Smaldino (1995), the noise levels in an occupied classroom are on the average, 10 dB greater (52 to 62 dB SPL) than when unoccupied. The American Speech-Language-Hearing Association standards for classroom acoustics recommend that the noise level not exceed 30 dB.

The American Speech-Language-Hearing Association reported that reverberation times within unoccupied classrooms can range from 0.4 to 1.2s, with a mean of 0.7s. An appropriate reverberation time for classrooms is 0.4 seconds or less. This suggests that the overall noise levels and reverberation time in the majority of classrooms surpass the recommended standards, hence the need to implement these standards in elementary classrooms.

Effects of Classroom Acoustics on Speech

A child's ability to aurally perceive a message along with his or her capacity to discriminate speech and language will be negatively impacted by elevated noise and prolonged reverberation time. A breakdown in the message being conveyed to the student, resulting from noise and reverberation, may result in a lack of substantial information for adequate speech understanding. This breakdown occurs when noise completely or partially masks portions of speech.

Neuman and Hochberg (1983) evaluated children's ability to understand speech in reverberant environments. The authors found that as reverberation time increased, speech intelligibility decreased. Pekkarinen and Viljanen (1990) investigated the effect of reverberant acoustic treatment on speech understanding in educational settings. The acoustic refitting improved speech discrimination especially in noisy environments.

Benefits to Measuring Classroom Acoustics

Measuring classroom acoustics gives an insight on the acoustical properties occurring in a classroom. It also provides information regarding whether or not the classroom is in accordance to the recommended standards. This information can assist an acoustical consultant in initiating strategies and recommendations to improve the learning environment. Following strategies and recommendations can decrease noise levels and reverberation time, which can increase speech intelligibility. This increase in speech understanding may lead to an increase in children's academic performance.

Modifications to the Classroom

Acoustical modification and communication strategies can assist in improving classroom acoustics and speech communication. Depending of the modifications, the prices can range from expensive to no cost. Implementing any modifications can assist in improving classroom acoustics.

Modification can occur outside or inside of the classroom. Outside modifications include planting shrubs along the classroom to decrease noise before entering inside the classroom. Also, windows can be replaced or sealed with non-hardening caulk to prevent the entrance of outside noise.

Internal modifications include installing carpet or area rugs, thick-heavy drapery, or acoustical ceiling tile to decrease the noise and reverberation in a classroom. If carpet is not an option, rubber tips can be installed on the legs of desks to prevent noise from the movement of desks. Any cracks in doors should be repaired with caulking or installing rubber gaskets to prevent outside noise.

Implementing communication strategies, which are at no cost, can also improve speech communication. The distance between the teacher and students should be minimized to decrease the amount of noise between the two. Background noise should be reduced as much as possible and the teacher should face the students when speaking so the children can visualize the mouth so that the speech is directed directly to the children.

Installing or implementing these strategies can greatly increase a child's ability to understand speech, hence, the need for the initiation of classroom acoustical measurements. It would be the responsibility of the acoustical consultant to measure the acoustical properties of the classrooms and provide strategies to enhance the learning environment. Many individuals may benefit from these modifications, such as students, teachers, principals, and superintendents. Students may have an improvement in speech intelligibility, teacher and principals may see an improvement in the children's academic performance and the superintendent may see an overall improvement in the school's academic standing.

APPENDIX B

LINCOLN PARISH SUPERINTENDENT'S PERMISSION LETTER

Lincoln Parish School Board
410 South Farmerville
Ruston, LA 71270

Dear Superintendent,

My name is Christal Savage and I am a fourth year audiology doctoral student at Louisiana Tech University. I am writing to request permission to conduct research in public schools in Lincoln Parish. The research involves measuring the acoustical parameters of classrooms.

The purpose of the study is to determine if the acoustical properties of reverberation and overall noise levels occurring in elementary classrooms can be improved to meet existing American Speech-Language-Hearing Association standards if they are presently not in compliance. If discrepancies exist, I would serve as an auditory consultant to recommend implementation or remediation strategies to enhance the acoustical properties of the classroom. The research will not require the participation of the teachers or the students due to the fact that the classrooms will be unoccupied, with the exception of classroom furniture, wall furnishings and accessories. The public schools I would like to include in the study are Choudrant Elementary, Cypress Springs Elementary, Glen View Elementary, Hico Elementary, Hillcrest Elementary, Ruston Elementary and Simsboro Elementary. Accordingly, permission will also be requested from the principal of each elementary school for the school to be used in the study.

Measuring the acoustical properties of an unoccupied classroom requires minimal time and equipment. The equipment consists of a digital recording device, amplifier, speaker and a sound level meter and the measurements will be obtained at various distances throughout the classroom. The measurement will occur before or after school or during recess or lunch break and should take approximately one hour to complete. It will not be necessary for the school system to provide any of the equipment as I will bring it with me.

Enclosed is a consent form which can be completed and mailed in the enclosed envelope if you wish to participate in the study. Please return the form no later than two weeks of receipt. Further information regarding the study is available at your request. Thank you very much for your time and effort in considering participation in the study.

Sincerely,

Christal Savage, B.A.
Audiology Doctoral Student
Louisiana Tech University
PO Box 3165
Ruston, LA 71272
(337-351-3018)

APPENDIX C

SCHOOL PRINCIPAL PERMISSION LETTER

Choudrant Elementary
PO Box 220
Choudrant, LA 71227

Dear Principal,

My name is Christal Savage and I am a fourth year audiology doctoral student at Louisiana Tech University. I am writing to request your participation in a research study to measure the acoustical parameters of seven public elementary classrooms in Lincoln Parish. The superintendent of the school system has given me permission to contact you to ask for your participation.

The purpose of the study is to determine if the acoustical properties of reverberation and overall noise levels occurring in elementary classrooms can be improved to meet existing ASHA standards if they are presently not in compliance. If discrepancies exist, I would serve as an auditory consultant to recommend implementation or remediation strategies to enhance the acoustical properties of the classroom. Participation from the teachers or students will not be required due to the fact that the measurements will occur in unoccupied classrooms with the exception of classroom furniture, wall furnishings, and accessories.

Inadequate reverberation time and overall noise levels can be detrimental to a child's understanding ability; hence, the need to comply with the national standards. Measuring acoustical properties of an unoccupied classroom requires minimal time and equipment. The equipment consists of a digital recording device, amplifier, speaker, and a sound level meter. A sound source will be presented through the speaker in which measurements will be obtained at various distances throughout the classroom using a sound level meter. The measurement will occur before or after school or during recess or lunch break and should take approximately one hour to complete. It will not be necessary for the school system to provide any of the equipment as I will bring it with me.

Enclosed is a consent form which can be completed and mailed in the enclosed envelope if you wish to participate in the study. Please return the form no later than two weeks of receipt. If you would like additional information regarding the study, an appointment can be arranged to discuss the study in further detail. Thank you very much for your time and effort in considering participation in the study.

Sincerely,

Christal Savage
Audiology Doctoral Student
Louisiana Tech University
PO Box 3165
Ruston, LA 71272
(337)-351-3018

APPENDIX D

REVERBERATION TIME AND OVERALL NOISE LEVEL RESPONSE FORM

Reverberation Time and Overall Noise Level Response Form

School______________________________ Date________________________

Classroom Volume___________________ Time_______________________

Overall Noise Levels Reverberation Time

	500 Hz	1000 Hz	2000 Hz		500 Hz	1000 Hz	2000 Hz
6 ft-front							
halfway							
Center							
halfway							
6 ft-back							

Average: ________ ________ _______ _______ _______ _______

Overall average of all frequencies:

___________________ ___________________

In Accordance with ASHA standards:

Overall Noise Level

Yes ______

No ______

Reverberation Time

Yes _______

No _______

APPENDIX E

CLASSROOM PHYSICAL PROPERTIES CHECKLIST

Classroom Physical Properties Checklist

School__________________________ Date_______________
Classroom Volume________________ Time_______________

Ceiling

Area of ceiling_________
Height of ceiling from floor________

Check all that apply:
What is ceiling composed of:
Acoustical ceiling tile______
Drop ceiling_______
Metal support beams______
Air ducts (if central air and heat)______ on/off_________
Other____
Explainations____
____
____

Walls and Windows

How many walls contain windows?_________ How many windows?__________
Condition of windows (cracks, double-paned, etc.)_________________________
____
Any window treatment (curtains, blinds etc.)______________________________

Composition of walls:
Cinderblock_________
Paneling____________
Dry wall____________
Other____
Any wall treatment (bulletin boards, chalkboard, posters, coat racks etc.)______
____
Air condition/heating wall units__________ how many____ on/off_____
Any closets within the walls__________________ how many_____________
Composition of doors (wood, metal)_____________ how many_____________

What is outside of the classroom (cafeteria, playground, bus stop, adjacent classrooms, etc.) ____
____
Explainations____
____
____

Floor

Area of floor______________

Floor coverings:

Floor tile:_____________

Carpet:_______________ if so, does it cover the entire floor?_________

Rugs:________________ if so, where are the rugs located (under desks, reading area)____

area of rugs____

Concrete:_____________

Other:_______________

Explainations:____

____

____

Classroom Arrangement

Number of desks_________

Number of students_____________

Arrangement of desks (column/rows, etc.)____________________________

Location of teachers desk ____

Location of teacher while teaching (standing in front, walking around, etc.)_____

____

Other classroom contents (ceiling fan, fish tank, book shelves, etc.)________________

____

____

APPENDIX F

PROTOCOL FOR MEASURING OVERALL NOISE LEVEL AND REVERBERATION TIME

Protocol for Measuring Overall Noise Levels and Reverberation Time

1. Determine room volume by measuring and calculating length, width, and height
2. Record on acoustical properties response sheet
3. Place compact disc player, amplifier, and speaker in the front left hand corner of the classroom
4. Set intensity level at 70 dB
5. Mark sound level meter placements on floor with tape (i.e., six feet from the center of the front wall, six feet from the center of the back wall, center of the classroom, halfway between the center of the room and the front six feet mark and halfway between the center of the room and the back six feet mark)
6. Calibrate sound level meter before measurements occur

Overall Noise Level

7. Place sound level meter on tripod at a height of four feet
8. Place sound level meter over first point, six feet from the center of the front wall and set the 10s delay
9. Start the sound level meter delay and step outside the classroom
10. Measure the overall noise level at the first distance at 500 Hz frequency weighting in dBA
11. The sound level meter will capture the peak measurement of the noise; record the measurement on the response sheet
12. Change the frequency weighting to 1000 Hz, set the 10s delay and step outside; record the measurement on the response sheet
13. Change the frequency weighting to 2000 Hz, set the 10s delay and step outside; record measurement on the response sheet
14. Continue to follow steps 9-13 for the remaining distances: six feet from the center of the back wall, center of room, midway between the front wall mark and the center of the room, and midway between the back wall mark and the center of the room

Reverberation Time

15. Place sound level meter on the mark six feet from the center of the front wall at a height of four feet and set the delay to 10s
16. Measure the reverberation time at 500 Hz frequency weighting in dBA
17. Start the sound level meter delay and walk outside of the classroom
18. Using the remote feature, start the compact disc player to generate the white noise stimulus
19. After 20 seconds, stop the stimulus so the sound level meter can automatically calculate the reverberation time
20. Walk inside and record the measurement on the response sheet
21. Change the frequency weighting to 1000 Hz, set the 10s delay and walk outside
22. Using the remote feature, start the compact disc player to generate the signal

23. After 20 seconds, stop the stimulus so the sound level meter can automatically calculate the reverberation time
24. Walk inside and record the measurement on the response sheet
25. Change the frequency weighting to 2000 Hz, set the 10s delay and walk outside
26. Use the remote to start the compact disc player
27. After 20 seconds, stop the stimulus so the sound level meter can automatically calculate the reverberation time
28. Walk inside and record the measurement on the response sheet
29. Continue to follow steps 16-28 for the remaining distances: six feet from the center of the back wall, center of the classroom, halfway between the front wall mark and the center of the room and halfway between the back wall mark and center of the room
30. After all measurements are obtained, recalibrate sound level meter
31. Average the noise level and reverberation time for each frequency weighting: 500, 1000, and 2000 Hz
32. For an overall noise level and reverberation time, average the responses for 500, 1000, and 2000 Hz for each acoustical parameter
33. Determine if the overall noise level and reverberation time is in accordance to the American Speech-Language-Hearing Association standards
34. Follow the same protocol for measurements occurring before or after school and during recess or lunch break

APPENDIX G

COMMUNICATION STRATEGIES FOR EDUCATORS

Communication Strategies for Educators

- Reduce all possible background noise and provide adequate lighting in the room so the children can visualize the teacher's facial cues and gestures.
- Face the children when speaking so the children can visualize the mouth so that the speech is directed directly to the children.
- Speech needs to be clear, spoken at a slightly slower rate and at a slightly higher intensity level.
- Do not cover the mouth or chew gum when speaking. This interferes with the child's ability to utilize visual cues while listening.
- The distance between the teacher and the students should be reduced so that the teacher's voice is at an appropriate intensity level. The maximum distance for effective speechreading is five feet.
- The teacher should also rephrase statements that were misunderstood to give the children another chance to understand the information. However, repeating the same sentence does not necessarily mean it will be understood a second time.
- Since some children speak softly, if a child asks a question or presents a statement to the class, the teacher should repeat what the child said to give all the other children an opportunity to hear what was said.

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