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Grant proposal: Effects of sound field amplification on standardized test scores

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Louisiana Tech University

GRANT PROPOSAL:

EFFECTS OF SOUND FIELD AMPLIFICATION ON STANDARDIZED TEST SCORES

by

Jessica Ivey Coker, M.S.

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
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Abstract

Research has shown that the majority of classroom environments lack appropriate acoustical standards to ensure optimal learning conditions. During the early school grades, it is especially crucial that students overcome poor listening environments to obtain the fundamental educational skills necessary for academic success. Furthermore, the State of Louisiana conducts standardized test assessments (LEAP and *i*LEAP) to measure the students' knowledge and skills gained. These standardized test scores not only determine if the student progresses to the next grade, but also influences the amount of federal revenue and how the revenue is allocated to the schools. A proposed remedy to reduce poor acoustics is to increase the signal-to-noise ratio in classrooms through the use of sound field amplification (SFA). To that end, the aim of this dissertation was to evaluate the potential benefits of SFA systems on standardized test scores in the elementary school age population through an extensive literature review that was used to develop a grant proposal. An appropriate grant proposal was developed in order to secure funding for the purpose of obtaining four SFA systems to be placed in 3rd and 4th elementary classrooms at the beginning of the school year in which they are scheduled to take the LEAP and *i*LEAP. Those scores will then be obtained and statistically analyzed to compare standardized test scores for students who are learning in classrooms with and without SFA. The American Hearing Research Foundation General Research Grant was deemed appropriate as this foundation awards four to six $20,000 grants each year for

research in the areas of hearing and balance. This current grant proposal request meets the criteria as described in the proposal guidelines.

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Chapter I

Introduction

In order for students to learn in a classroom environment, they must be able to hear and focus on what the teacher is saying. Several studies have shown that listening and learning becomes compromised due to poor classroom acoustics (Anderson & Goldstein, 2004; Crandell & Smaldino, 2000). For instance, high reverberation times (RTs) and increased background noise have been known to negatively impact learning as well as students' social and emotional behavior (Klatte & Hellbruck, 2010; Wilson, Marinac, Pitty, & Burrows, 2011). To ensure ideal learning conditions, the American National Standard Institute (ANSI) has developed standards for classroom acoustics that are designed to achieve optimal speech intelligibility for students in typical classrooms (ANSI, 2010). Unfortunately, the majority of classrooms fail to meet these favorable standards and many children continue to experience academic difficulties due to internal and external classroom noise, reverberation, speaker-to-listener distance, and poor classroom acoustics (Rosenberg et al., 1999).

To help overcome the acoustical learning barriers, sound field amplification (SFA) devices have been recommended by researchers, clinicians, and educators (Wilson et al., 2011). SFA consists of a microphone worn by the teacher (or speaker). The teacher's voice is amplified and sent to loudspeakers, which are placed around the classroom. Therefore, all the students are able to hear the teacher's voice regardless of the distance or location of the teacher in the classroom. Many studies have documented the benefits of SFA for children with normal hearing, hearing impairment, and developmental delays (Anderson & Goldstein, 2004; Langlan, Sockalingam, Caissie & Kreisman, 2009; Rosenberg, et al., 1999; Rubin et al., 2011; Wilson et al., 2011). These benefits include improved overall academic achievement, speech recognition, literacy, phonological awareness, reading comprehension, listening comprehension, attention and learning behaviors (Anderson & Goldstein, 2004; Rosenberg, et al., 1999; Rubin, Flagg-Williams, Aquino-Russell, & Lushington, 2011; Wilson et al., 2011). While the benefits of SFA are prevalent for all children, the actual implementation of SFA systems in the educational system is rather scarce.

A search of current literature revealed a lack of research addressing the effects of SFA on state mandated standardized test scores. For the purposes of this paper, a standardized test is defined in accordance with the requirements stated in the No Child Left Behind Act of 2001. According to the United States Department of Education (USDE, 2002), the federal No Child Left Behind Act requires every state to administer an annual test in the core subjects of reading and math in grades three through eight and at least once in grades 10 through 12. Also students are to be tested in science in at least one grade in elementary, middle and high school. Schools must be in compliance with this law in order to maintain federal and state funding (USDE, 2002).

The Louisiana Educational Assessment Program (LEAP) test is a series of tests that fourth and eighth-grade students take each year to determine if they need summer school remediation or to be retained. This high stakes test is based on Louisiana's Grade Level Expectation which measures students' knowledge and skills in English language arts, mathematics, science, and social studies. In order for a student to proceed to the next grade level, according to the Louisiana Department of Education (LDOE, 2011) website, "students must score *basic* or above in either English language arts or math and *Approaching Basic* or above in one other subject." The *i*LEAP or "integrated" LEAP is a standardized test administered in grades three, five, six, and seven in Louisiana. These tests are congruent with Louisiana's content standards, benchmarks, and Grade Level Expectations in areas of English language arts, mathematics, science, and social studies. The *i*LEAP measures students' progress by comparing norm-referenced tests and criterion-referenced in order to evaluate the students' performance to a national sample and the state's achievement levels.

The LEAP and *i*LEAP scores are used as a direct representation of the school districts' and students' proficiency achievement level (i.e., schools are graded and ranked by how well the students perform on these tests each year). Failure to show adequate yearly progress towards the statewide goals results in corrective action and restructuring measures aimed to help the school acquire state standards. Schools meeting or exceeding these goals or showing improvements in achievement gaps are eligible for State Academic Achievement Awards as well as more flexibility in using Federal Education funds (U.S. Department of Education, 2002).

In summary, many classroom environments lack appropriate acoustical standards to ensure optimal learning conditions (Crandell & Smaldino's 2000; Eriks-Brophy & Ayukawa 2000; Knecht et al., 2002; Larsen & Blair 2008; Nelson et al., 2005; Wilson et. al, 2011). During the early school grades, it is especially crucial that students overcome poor listening environments to obtain the fundamental educational skills necessary for academic success. The state of Louisiana conducts standardized test assessments (LEAP and *i*LEAP) to measure the students' knowledge and skills gained during that grade. These standardized test scores not only determine if the student progresses to the next grade, but also influence the amount of federal revenue and how the revenue is allocated to the schools. A proposed remedy to reduce poor acoustics is to increase the signal-to-noise ratio in a classroom through the use of SFA. The purpose of this paper is to write and ultimately submit a grant to purchase SFA systems to be placed in classrooms that will undergo standardized testing. It is hypothesized that the use of SFA in the classroom will result in higher scores on the LEAP and *i*LEAP, and not only aid in improving overall student academic performance, but also demonstrates the value and necessity of utilizing SFA in education.

Chapter II

Review of Literature

Classroom Acoustics

The predominant teaching method used in mainstream classrooms is auditory verbal; however, the acoustical environment in today's classrooms poses many challenging obstacles to listening and learning for young school aged children. Within the classroom, factors such as internal and external background noise, reverberation, speaker-to-listener distance, and poor acoustical treatments can interfere with listening and learning (Eriks-Brophy & Ayukawa, 2000). Often these variables are compounded with other issues such as a hearing impairment, learning disability, auditory processing disorders, or English as a second language.

Recommended acoustical standards. It is well established that the better children can hear, the more he/she can understand and learn (Anderson & Goldstein, 2004; Wilson et al., 2011). Furthermore, extensive research has shown that unfavorable acoustic conditions in the classroom diminish speech audibility and intelligibility, have detrimental effects on a student's psychoeducational and psychosocial achievement, and create negative effects on a teacher's energy level and vocal health (Anderson & Goldstein, 2004; Berg, Blair, & Benson, 1996; Klatte & Hellbruck, 2010; Rosenberg, et al., 1999; Rubin et al., 2011; Wilson et al., 2011). In an effort to rectify unfavorable listening environments and promote successful learning environments, the Acoustical Society of America and American National Standards Institute (ANSI) developed the

ANSI S12.60 standard (ANSI, 2010). In conjunction, the ANSI standard recommendations are also supported by the American Speech-Language-Hearing Association (ASHA, 2005). The ANSI (2010, 2009) recommendations state that (1) permanent and unoccupied classroom levels should not exceed 35 dB; (2) SNR should be no less than +15 dB; and (3) unoccupied classroom reverberation time must not surpass 0.6-0.7 seconds; the standards set by ASHA (2005) recommend that RT should not exceed 0.4 s. Currently, compliance with the ANSI standard and ASHA recommendation is voluntary. Many school districts, states and local agencies are now beginning to incorporate these standards into their construction or renovation efforts to improve classroom and school acoustics; however, a large majority of classrooms fail to meet ANSI criteria for optimal classroom acoustics (ASHA, 2005). Both ANSI and ASHA address three main acoustical parameters that interfere with the quality of the classroom listening and learning environment: background noise (BN), signal-to-noise ratio (SNR), and reverberation time (RT). In a classroom, BN is any unwanted sound(s) that interferes with the teacher's voice. The SNR is a measurement of how much noise is present in the classroom in relation to the signal (i.e., teacher's voice). Lastly, reverberation is the prolongation of sound that lingers after the original sound has ended. For instance, it can be thought of as the amount of echo in the classroom (Tye-Murrary, 2009). The implications of these three acoustical variables on classroom acoustics are discussed below.

Background Noise. One basic acoustical parameter that affects a child's ability to learn in the classroom is background noise. In a review article by Crandell and Smaldino (2000), BN is defined as any unwanted auditory stimulus that interferes with what the listener wants or needs to hear. In essence, BN is extraneous sound(s) that masks the signal of interest. BN can be categorized as external noise, internal noise, and classroom noise. External noise is comprised of sounds from outside the building, such as playgrounds, automobile traffic, airplane traffic, local construction or outside air-conditioning units. Internal noise arises from within the building but outside the classroom, such as adjacent rooms, gymnasiums, and busy hallways (Tye-Murrary, 2009). Room noise originates from inside the classroom and includes shuffling papers, moving chairs or tables, children talking, and heating, ventilating, and air-conditioning (HVAC) systems. Measurements of BN are typically made on a sound level meter and are recorded as relative sound pressure levels (SPLs) at specific points in time on an A-weighted scale (dBA). The A-weighted scale is commonly used because it represents the sensitivity of an average human ear under conditions of low sound loudness (i.e., 40 phons).

Crandell and Smaldino (2000) reviewed past investigations of the acoustical environment in classrooms. They reported that the acoustical variables of noise, reverberation, and distance were all shown to directly influence speech perception. They further reported that inadequate classroom acoustics can have detrimental effects on academic, psychoeducational, and psychosocial performance not only for children with hearing impairments but also for those with normal hearing sensitivity. Crandell and Smaldino (2000) further discussed the parameters of BN that disrupt the child's ability to hear and understand speech in a classroom. The long-term spectrum of the background noise, intensity fluctuations of the noise over time, and the intensity of noise relative to speech were all listed as influential parameters that reduce the ability to perceive speech.

For instance, consonants have relatively low intensity energy in comparison to vowel sounds, thus BN in the classroom tends to overshadow consonant perception; therefore, significantly reducing the ability to understand them. Furthermore, if the long-term spectrum of the background noise is similar to the speech frequencies of the signal, the noise becomes an effective masker of the speech signal. An example would be BN due to children talking, which has the same spectral content of the teacher's voice. Lastly, noises that are continuous are more effective maskers than interrupted or impulse noises since continuous noises can reduce the spectral-temporal cues in the speech signal. Examples of continuous noises include air conditioning /heating systems or the hum of a faulty fluorescent light or a computer fan running.

Furthermore, research has continually demonstrated how noisy a typical classroom can be. In Crandell and Smaldino's (2000) review of literature, they found that unoccupied classroom BN levels ranged from 41 to 51 dBA, and occupied classrooms measurements were from 48 to 68 dBA. Furthermore, Nelson, Kohnert, Sabur and Shaw (2005) estimated that many busy occupied classrooms reach BN levels of 70 dBA or higher. Additionally, Wilson et al. (2011) measured BN levels in four typical different types of classrooms, such as locations in brick buildings or in a portable building. Their results showed BN levels from 47 to 62 dBA. Likewise, Knecht, Nelson, Whitelaw, and Feth (2002) examined the BN levels of classrooms with the HVAC unit on and off. When the HVAC unit was off, the noise levels measurements of the classrooms averaged at 39.8 dBA and an averaged 49.7 dBA when the unit was on. Lastly, a study by Eriks-Brophy and Ayukawa (2000) revealed occupied classroom noise level measurements from 57.6 to 61.9 dBA. The BN measurements from the aforementioned studies provided evidence that the typical classroom noise levels are substantially higher that the ANSI standard recommendations of 35 dBA.

A similar study of acoustics conducted by Rubin, Flagg-Williams, Aquino-Russel, and Lushington (2011) analyzed various aspects of classroom listening environments in eight schools across three Canadian school districts with the purpose of making recommendations for improving listening and learning. Particularly, they evaluated the hearing status of 947 students in kindergarten through third grade. Then, measurements of the classroom noise level were made with and without SFA, and teachers and student opinions regarding SFA were obtained.

Hearing screenings were conducted on 947 students. Normal hearing was defined as follows: 500Hz (25 dB), 1000 Hz (20 dB), 2000 Hz (20 dB), and 4000 Hz (20 dB). SFA systems were employed in 31 classes, equaling 610 students in the amplified group, and 29 classes were without amplification, totaling 552 students in the unamplified group. Experimental classrooms were provided with Phonic Ear Frontrow Pro infrared SFA with four mounted speakers and a wireless pedant microphone. Noise level measurements were taken to calculate the overall background noise level. Furthermore, classroom observations were obtained with the *Revised Environmental Communication Profiles* (RECP) protocol. The RECP allowed for recoding of the student's verbal and nonverbal communication and whether communication was directed to the teacher or the student's peers. Group interviews were also conducted to obtain teacher and student perceptions of the SFA.

The authors found that 88% of the 947 students had adequate hearing for the study. Mean background noise levels ranged from 33.6 to 52.3 dBA in the schools. All 14 classrooms in School X failed to meet the ANSI standard for classroom acoustics. Rubin et al. (2011) further showed that 85% of the students responded more when the teacher addressed them in the amplified condition (i.e., with SFA). When the teacher addressed the class, there was a significant decrease in distractive communicative interactions among students for the amplified classroom. Lastly, interviews with teachers and students revealed the overall ratings of the SFA were generally positive (87%) with only a few problems noted, such as issues with feedback and setting the volume too high.

Based on the findings from Rubin et al. (2011), the researchers suggested the importance of hearing screenings in detecting hearing problems in young students. Furthermore, only 31% of the classrooms tested met ANSI recommended standards, suggesting that classrooms with poor acoustics demanded more energy for students to focus and concentrate. Furthermore, the researchers concluded that the use of SFA reduced distractive communicative behaviors and improved the students' ability to focus. The authors recommended school personnel to be conscious of the important factors of creating optimal classroom listening environments through knowing the students' characteristics, room acoustics, and the effectiveness of SFA.

Signal-to-noise ratio. A second crucial variable to consider within the classroom environment is the SNR. SNR is the difference in decibels between the intensity levels of the speech signal compared to the intensity levels of the noise. The SNR relationship is favorable when the signal is higher than the background noise. Conversely under increased background noise, the SNR decreases resulting in poor listening environments. As previously stated, ANSI (2010) and ASHA (2005) standards recommend at least a +15 dBA SNR for adequate speech perception to occur in the classroom; however, the typical SNR surpasses this limit. For instance, Crandell and Smaldino's (2000) review of literature showed that SNRs in typical classrooms ranged from +5 dB to -7 dB, indicating excessive noise levels in most learning environments. Furthermore, evidence has shown BN levels for occupied classrooms at 70 dBA or higher, which results in a SNR 0 to -5 dB for the average speaker (Rubin et al., 2011).

Several studies have evaluated the problematic effects of degraded SNR in the classroom. For example, one study by Larsen and Blair (2008) evaluated the SNR of a classroom while class was in session and students were interacting with the teacher and peers. They stated that the current literature examining the benefits of increased SNR with students in a classroom with the use of SFA is insufficient. To overcome this scarcity, they sought to accomplish three purposes. The first objective was to collect SNR data from occupied classrooms at nine positions. Secondly, they evaluated the SNR of the teacher's voice in the amplified (i.e., with SFA) and unamplified (i.e., without SFA) conditions. Lastly, they acquired data for the SNR of the student's speech in the unamplified and amplified conditions when the students used a hand-held microphone that was passed around the classroom.

The classroom selection was made from four similar fourth-grade classes in the state of Utah. Surprisingly, these classrooms met ANSI guidelines for classroom acoustics. The classrooms were installed with an Audio Enhancement Ultimate 200 dual channel infrared system with four ceiling mounted speakers. A time, energy, frequency (TEF) system was implemented (Techron TEF System-20) to obtain acoustical measures of unoccupied and occupied classrooms noise levels and RTs. TEF measurements of the SNR were taken at 10 minute intervals at nine different positions in each classroom. The examiner documented the classroom activities during each measurement to determine the source of the sound. Averages of the teacher's speech, child speech, and child group noise levels were also obtained.

Larsen and Blair (2008) found unoccupied classroom measurements demonstrated favorable acoustics for the speech signal transmission. The amplified SNR from the teacher's speech ranged from +11 to +15 dB. The unamplified SNR measurements for the teacher's speech were significantly lower (+1 to +6 dB). Measurements of the SNR at nine different positions in the unamplified classroom revealed a range from +3.0 to -17.6 dB. Occupied measures of the child's talking to the class showed a SNR ranging from +9 to -3 dB. Further, the authors showed a +13 dB SNR when the microphone was used by the students in the classroom. Therefore, this study provided evidence that when the classroom acoustics are favorable, SFA has the ability to increase the SNR by approximately +13 dB compared to the noise floor for all students across the classroom. Also results of the students' speech SNR indicated that without the use of SFA, students may miss what other students are saying (Larsen & Blair, 2008).

Similar studies have demonstrated the benefits related to improving the SNR with the use of SFA in the classroom. Specifically, Eriks-Brophy and Ayukawa (2000) conducted a three-month pilot study to investigate the potential benefits of SFA for first and second language learners of Inuit students in the uniquely isolated community of Nunavik, Northern Quebec. This study aimed to document the usefulness of SFA by investigating student performance on speech intelligibility measurers, attending behaviors, and teacher and student statements concerning SFA. In each of the three classrooms tested, an Easy Listener sound field FM system by Phonic Ear Corporation was installed. Measurements of the SNR were obtained first without the use SFA revealing a range from + 1.2 to + 4.8 dB. With the use of SFA, the SNR increased to a range of + 2.8 to + 10.2 dB. Secondly, the speech intelligibility measures revealed that both students with and without hearing loss had significant improvements in speech intelligibility scores when the SFA system was in use. Specifically, those with hearing loss exhibited a 39% average improvement on speech intelligibility scores with SFA, while the normal hearing group showed an improvement of 23%. Thirdly, behavioral observation measures in the amplified condition showed significant improvements in attending behaviors. The overall ratings of the SFA systems were positive and well accepted in the classroom by the teachers and the students.

With the unique educational arrangement of the Inuit students, Eriks-Brophy and Ayukawa (2000) demonstrated the benefits of SFA for students with hearing loss, behavioral difficulties, normal hearing, attention or behavioral difficulties, as well as second language learners. The authors study showed significant increases in speech intelligibility as well as in attending behaviors. Eriks-Brophy and Ayukawa (2000) concluded that SFA systems are valuable in other educational circumstances that differ from typical mainstream classrooms, and especially applicable to multicultural populations with high rates of hearing loss.

Reverberation time. The third influential acoustical variable that can have devastating effects on listening and learning in the classroom is reverberation. As previously stated, reverberation is the prolongation of sound after the signal has stopped. Specifically, the RT in a room refers to the amount of time it takes for the sound to diminish by 60 dB once the source of the sound has ended (Berg et al., 1996; Crandell & Smaldino, 2000; Dockrell & Shield, 2012). Longer RT results in substantial negative effects on speech intelligibility. RT becomes a problem because it affects speech perception by reflecting back to the listener and overlapping fragments of the original signal. This results in a masking or "smearing" of the speech signal. Specifically, reverberation causes the more powerful spectral energy of vowels to be prolonged, which masks subsequent consonant phonemes. In highly reverberant environments, prolongation of whole words may overlap and fill in temporal gaps between words and sentences further misconstruing the original message (Knecht et al., 2002).

There are two factors that influence the RT in a room as described by Crandell and Smaldino (2000). The first deals with the size or volume of the room. For example, larger room volumes produce longer RTs. The second factor is the amount of sound absorption material in the room. The more the sound is absorbed, the smaller the RT value. RT varies as a function of frequency and is regularly reported as an average decay time at 500, 1000, and 2000 Hz. According to the ANSI (2010) recommendations, RT for a small unoccupied classroom (i.e., a room smaller than 10,000 ft^3) should not exceed 0.6 s or 0.7 s for a larger classroom (i.e., a room bigger than 10,000 ft^3). The recommendations for unoccupied classrooms set by ASHA (2005) state that the RT should not exceed 0.4 s. When looking at the RT in relocatable (i.e., portable building) classrooms, ANSI (2010) recommends that the RT in a small unoccupied classroom should not exceed 0.5 s while the RT in a larger classroom should not exceed 0.6 s. Unfortunately, studies of typical classrooms RT values do not meet these recommendations. For instance, Crandell and Smaldino (2000) reported RTs from five studies ranging from 0.4 to 1.20 s. Likewise, Wilson and colleagues (2011) measured RTs in unoccupied permanent and relocatable classrooms and found RTs ranged from 0.72 to 1.09 s. All of these studies exceed both ANSI (2010) and ASHA (2005) standards for optimal communication.

To further investigated the effects of classroom reverberation on children's learning ability, Klatte and Hellbruck (2010) examined reading abilities, annoyance due to indoor noise, and school attitudes. They hypothesized that poor classroom acoustics caused children to feel annoyed more than students in classrooms with better acoustics. They also theorized that children and teachers exposed to poor classroom acoustics over long periods of time have detrimental consequences on their social and emotional attitudes resulting in an impaired learning environment.

Their study included 17 classrooms from eight schools in Stuttgart, Germany, with RTs ranging from 0.49 to 1.1s. Participants included 398 second graders divided into three groups based on RTs. The first group, labeled as RT_1, entailed 126 subjects in five classes from two schools with RTs smaller than 0.6 s. Group 2, labeled as RT_2, consisted of 175 participants in eight classrooms from five schools with RTs from 0.69 to 0.92 s. The last group, RT_3, had RTs longer than 1s and consisted of 97 participants from four classrooms across three schools. To examine reading performance, a standardized reading test called the Salzburger Lese screening was used. This test requires students to read a sentence silently and determine if it is true or false. Furthermore, nonverbal intelligence was assessed using the Colored Progressive Matrices, which display visual patterns that have a missing item. Students were asked to select the missing part. Thirdly, phonological processing was measured using a task called "odd one out," which has been shown to indicate reading and spelling ability. Specifically, students were asked to identify which word or non-word in a set of three did not belong based on the initial or ending sounds. This task used a loudspeaker at 65 dB (A) to present the words or non-words, and then a second later provided a visual cue to indicated which part of the word was to be examined (i.e., beginning or ending sounds). Additionally, questionnaire assessments included: (1) a noise questionnaire examining the teachers' and students' views of classroom noise; (2) social and emotional school attitudes; (3) a parental questionnaire on sociodemographic variables; and (4) the child's annoyance level due to the classroom noise. The experiment was conducted over eight weeks. Sound absorbing materials were installed during the study for the phonological processing tasks to ensure favorable interior acoustics during testing.

Klatte and Hellbruck (2010) found no significant difference among the groups with respect to sociodemographics. For the three groups, reading performance was not significantly different; however, analysis of phonological processing task revealed a significant main effect for classroom reverberation. Specifically, the results showed that group RT_1 with shorter RTs performed significantly better than the other groups with medium (RT_2) and long reverberation (RT_3). Specifically, the mean percent correct scores for RT_1, RT_2, and RT_3 were 70.3%, 64.7%, and 61.7%, respectively. This indicated that students from classrooms with the lower RTs were able to perform better than those students from classrooms with higher RTs, even when the acoustics conditions were controlled during the testing session. The ratings for indoor noise levels were also lower for classrooms with shorter RTs. Further analysis of children's annoyance due to indoor noise also found that classroom RTs played a significant role. Again, results showed the ratings for indoor noise were lower (i.e., more positive rating) for the students in classrooms with the shorter RTs when compared to the higher scores (i.e., more negative rating) of the medium and long-reverberation group. A similar result was found on the parental survey which asked, "My child suffers from the noise produced by his/her classmates at school." Parents of children in group RT_3, which had long RTs, reported the highest percentage of child annoyance due to classroom noise. Lastly, RT was significantly correlated with students' reported social and emotional school experience. Specifically, those with the long RT (i.e., RT_3) reported more negative interactions with their teacher than those with short and medium RTs.

In conclusion, Klatte and Hellbruck (2010) consistently found that the classrooms with the shorter RTs outperformed classrooms with longer RTs, even when differences in nonverbal intelligence, sociodemographic variables, and testing conditions were accounted for. The results suggested that long-lasting experiences in adverse listening conditions may weaken the development of phonological processing skills, which are the precursors that aid in reading and spelling ability. Also, the authors infer that poor acoustics, such as an increase in ambient noise due to the higher RT, leads to students' perception of more annoyance by the noise, subsequently reflecting poorer reading abilities and school attitudes.

Furthermore, Knecht, Nelson, Whitelaw, and Feth (2002) examined the acoustical properties of 32 randomly selected elementary classrooms in three Ohio school districts. Specifically, they measured RTs, BN, and classroom dimensions (length, width, height, and room volume) and then compared their results with ANSI (2010) acoustical standards for classrooms. To determine the acoustical characteristics of the classrooms, unoccupied noise measurements and unoccupied RTs were made at five different positions in each room. BN levels were measured with an A-weighted sound level meter and RTs were expressed as an average for 0.5, 1, and 2, KHz.

Knecht et al. (2002) showed that the BN levels ranged from 34.4 to 65.9 dBA. More specifically, only four classrooms measured below 35 dBA, and only one classroom measured below the more conservative criterion suggested by ASHA, 30 dB(A). Their results indicated that overall, the 32 classrooms were 5 to15 dB higher than the recommended standards for background noise. Furthermore, the RT recordings showed that only six of the 32 classrooms met the criteria of 0.4 s recommended by ASHA and 19 classrooms met the 0.6 s recommendation set by ANSI. Additionally, they discovered that RTs were directly related to the size of the classroom. The rooms with the lowest ceilings (10 ft. or less) were reported to have RTs that met both the ASHA (2005) and ANSI (2010) standards. Moreover, the rooms with the largest volumes also had the longest RTs. The authors also found that none of the rooms with the HVAC (heating, ventilation, and air conditioning) system turned on met the recommended level of noise set by either ASHA (2005) or ANSI (2010). Furthermore, the classrooms in the newer schools had the lowest levels of BN and better RTs, while all of the older classrooms in the other schools exceeded both criteria. Based on these results, the authors suggested that new classrooms have improved classroom acoustics over the older ones due to newer sound-absorbing windows and building materials. As expected, these results indicate that larger rooms have substandard RTs, HVAC units introduce noise levels that exceed noise standards, and newer classrooms are more likely than older classrooms to meet minimum noise standards.

Additionally, Dockrell and Shield (2012) examined the impact of SFA on teaching and learning in elementary classrooms by identifying specific acoustical classroom conditions (i.e., average RT) where amplification seemed more advantageous. Their work differed from previous studies in that they focused on older elementary groups and used certified researchers instead of teachers to sample performance of academic and nonacademic tasks. They hypothesized that the use of SFA would (a) improve listening, therefore boost academic performance; (b) improve the SNR, leading to increased auditory processing and subsequently improve verbal task; and (c) improve behavior and attention leading to general enhancements in overall classroom performance.

The methods of the study included questionnaire surveys and experimental testing of students as well as questionnaires compiled by teachers in classrooms with and without SFA. A sample of students from 458 elementary schools in southeast England was used. Baseline examinations were carried out before installation of the SFA, and post-testing occurred six months after installation for amplified and non-amplified comparison classrooms. Seven hundred forty students completed baseline questionnaires and 478 students completed follow-up questionnaires. Data for 393 students were analyzed representing 19 classrooms total. Of the 19 classrooms, 14 had SFA and 5 were comparison classrooms. Teachers of the test classrooms were also assessed with follow-up questionnaires. Of those, the experimental participants included 186 students from eight classrooms (five amplified and 3 control) ranging from ages 8-11 years. Approximately 15% (28 students) were identified as having special educational needs and 13% (25 students) had English as an additional language. A qualified psychologist carried out the assessment of students in their classrooms. The questionnaires were measured with a smiley face Liker scale, or with a rating of one to five, one indicating the student could hear and five that it was difficult to hear. Awareness of 11 typical environmental classroom noises as well as teacher and student perception of audibility in eight dissimilar classroom situations was examined. Also, teachers of classrooms with SFA were asked to report their use of the system, which classroom activities were performed while using the system, and rate the impact of the system on the following: students' understanding of spoken language, attentiveness, changes in behavior, and rate of learning. Academic and cognitive skills were measured using well known and valid test measures standardized in the U.K. (i.e., Suffolk Reading Scale, British Ability Scales II: Spelling scales, British Ability Scales II: Numeracy scale, Speed-of-Information Processing Test from British Ability Scales II, and Listening Comprehension Test Series). For details of the aforementioned test see Dockrell and Shield (2012). An acoustic survey including measurement of RT was also completed in the schools where the SFAs were to be installed.

After the six-month period, 11 of 16 teachers were using the SFA and five had stopped doing so. Three of the later reported that the system was uncomfortable to use. Also, the teachers who used SFA showed positive ratings in the following areas: students' ability to understand spoken instructions, use of appropriate answers to questions, improved attention in quiet and background noise, and less need for teacher's vocal strain. The responses of the student questionnaire survey revealed that the SFA had no impact on their perception of external sounds. Furthermore, initial experimental tasks showed no significant difference between amplified and comparison classrooms at baseline testing measures of spelling, numeracy, speed of information processing, accuracy of information processing, reading accuracy, and listening comprehension. Moreover, increased performance was found for students in the amplified classrooms on the nonverbal processing task. Students with SFAs also showed improvements in listening comprehension when compared to the non-amplified classes. There was, however, no significant correlation for the effect of time (i.e., the differences among baseline and six month follow-up). Academic test further revealed that regardless of SFA used, students' performance improved over time. Notably, students with special needs showed mark improvement from the use of classroom amplification. Lastly, measurements of RTs showed a wide distribution from 0.2 to 1.19 for the classrooms that were surveyed. Of the rooms with SFA, a comparison was conducted between classrooms with good acoustics for speech (RT$\leq$ 0.52) and those with poor acoustics (RT $\geq$ 0.83) on speed of processing, listening comprehension, and academic tests; a significant effect was noted for listening comprehension only. Furthermore, more noticeable gain was made on listening comprehension in the classes with poorer RT versus those with good RTs measurements.

According to Dockrell and Shield (2012), the use of SFAs improved listening and attending to verbal instruction as measured by teacher ratings and student performance. The researchers were surprised to find that SFA did not improve overall academic achievement. Furthermore, they found that classroom amplification significantly improved the student's understanding of spoken language. Notably, the results showed that classrooms with poorer acoustics (longer RTs) showed greater improvement in listening comprehension with SFAs in contrast to the students in rooms with better acoustics (shorter RTs).

In summary, there are three well know acoustical parameters that dramatically influence the listening environment in a classroom: background noise, signal-to-noise ratio, and reverberation. Research has shown that unfavorable classroom acoustics can diminish speech audibility and intelligibility, have detrimental effects on a student's psychoeducational and psychosocial achievement, and negatively impacts teacher's energy levels and vocal health (Berg et al., 1996; Klatte & Hellbruck, 2010). In an effort to rectify unfavorable listening environments and promote successful learning environments, both ANSI (2010) and ASHA (2005) have established recommended guidelines for these three parameters. Furthermore, research has continually demonstrated that the typical classroom BN levels range from 39.8 to 70 dBA, which is substantially higher than the ANSI standard recommendations of 35 dBA (Crandell & Smaldino, 2000; Eriks-Brophy & Ayukawa 2000; Nelson et al., 2005; Knecht et al., 2002). A second acoustical parameter, SNR, has also consistently been shown to exceed ASHA (2005) and ANSI (2010) recommendations of +15dB SNR in classrooms. For instance, research examining SNRs in typical unoccupied classrooms have been reported to range from +5 dB to -7 dB and in an occupied classroom to range from +3.0 to -17.6 dB (Crandell & Smaldino's 2000; Larsen & Blair 2008). Similar studies have demonstrated the benefits related to improving the SNR with the use of SFA in the classroom. For example, Larsen and Blair (2008) recorded SNRs from the teacher's speech ranging from +11 to +15 dB with the use of SFA. Furthermore, Eriks-Brophy and Ayukawa (2000) demonstrated the benefits of improving the SNR with the use of

SFA for students with hearing loss, behavioral difficulties, normal hearing, attention or behavioral difficulties, as well as second language learners. Reverberation is the third acoustical parameter that can negatively affect listening and learning in the classroom. Research evaluating the average classroom RT has also documented that these measurements commonly exceeded the recommend ASHA (2005) and ANSI (2010) RT standards (Crandell & Smaldino, 2000; Knecht et al., 2002; Wilson et al., 2011). Other studies have document that improving the RT time can lead to improvements in reading abilities, less annoyance due to indoor noise, and more positive attitude towards school (Klatte & Hellbruck, 2010).

In conclusion, unfavorable classroom acoustics such as long reverberation times, poor SNR, and increased BN have all been shown to significantly impede children's ability to listen and learn in a classroom. As demonstrated in the above, research continually shows how poor acoustics negatively impact not only children with normal hearing but those with hearing loss and other learning disorders. Through improving poor acoustical parameters, research has numerously demonstrated the positive effects such as improved listening ability, increased academic performance and better classroom behavior.

Assistive Listening Devices

Performing structural modifications to ameliorate poor classroom acoustics may not always be feasible. However, the use of alternative listening devices has been proven beneficial and cost-effective in reducing the negative effects associated with poor classroom acoustics (Boswell, 2006). There are several different types of assistive listening devices such as personal frequency modulated (FM) systems, infrared systems, induction loop systems, and SFA systems that have been used to help students hear the teacher and overcome adverse listening conditions (ASHA, 2002; Kreisman, 2002). Generally, each system has a microphone that is worn near the speaker/teacher's mouth. The input signal (i.e., teacher's voice) enters the microphone and is amplified and sent to a receiver, which is used to transmit a louder signal to the listener/student (Tye-Murrary, 2009). The receiver transmits the amplified sound to the individual's ears. There are also different types of receiver coupling options that can be utilized by the FM system. For example, some receivers are designed to be as a body-worn device or can connect to a behind-the-ear hearing aid via a direct audio input, neckloop, or FM boot (Lewis, 1994a). The various FM systems and their coupling modes will be discussed in greater detail below.

Ear level FM systems. For those with a hearing impairment, ear level FM systems are commonly used in the classroom (Lewis, 1994a). An ear level FM system transmits sound directly from teacher's microphone to a receiver that converts the electrical signal back to an acoustic waveform and sends it to the listener's ears. Two commonly used ear level systems are personal FM systems and self-contained FM systems. A personal FM system consists of two parts: a wireless transmitter and a small receiver, which is coupled to the child's hearing aids or cochlear implant (Lewis, 1994b). A receiver for a personal FM system can be coupled to a child's hearing aids in various ways (Tye-Murrary, 2009). One way is with the use of a small discrete device that attaches to the base of behind-the-ear (BTE) hearing aid called an "FM boot" or "audio shoe," which houses the FM receiver. This type of receiver coupling is also known as direct audio input (DAI). DAI utilizes a hardwired connection from the sound source to the hearing aids. It has been reported that coupling via DAI may provide the best benefit for speech recognition in noise for individuals with hearing loss (Thibodeau, 2010). Research has also found that the FM response was more similar to the hearing aid response when using the DAI coupling arrangement (Lewis, 1994a). Some systems also use a neckloop transducer. This is a lariat style cord worn around the neck that receives the signal and transmits it via magnetic induction to the telecoil in the user's hearing aids. Lastly, some hearing aids are equipped with a built-in FM receiver (Lewis, 1994a).

The second type of ear level FM system is called a self-contained. A self-contained FM consists of a transmitter and a receiver, however it differs from a personal FM system since it usually is worn in place of hearing aids. This system resembles a small Walkman style device that is worn by the listener and acts as a receiver picking up the FM radio waves transmitted from the wireless microphone worn by the speaker. This system amplifies the speech signal independent of hearing aids (ASHA, 2002). The output of the self-contained FM system is amplified and delivered to the listener through various coupling options such as button transducers, insert earphones, headphones, earbuds, BTE transducers, or a bone conduction transducer (ASHA, 2002; Lewis, 1994a).

Both personal and self-contained FM systems have many benefits in the classroom due to their portability. These devices can be used in multiple rooms within the same school building (Lewis, 1994a). They have the flexibility to work with a variety of hearing losses, and depending on the type selected they can be used with or without personal amplification. Additional advantages of using a self-contained unit in the school system include its affordability and its repeated use over the years. Self-contained FM systems have the added benefit of not requiring the use of hearing aids; thus it can be worn if the child's aids are not functioning properly or in need of repair. However, a self-contained unit is not recommended for children with more than a moderate hearing loss (ASHA, 2002). There are also other potential limitations to consider for personal and self-contained FM systems. For instance, the use of cords as a coupling mechanism may be a drawback when used with smaller children. For both systems the listener must wear the receiver which may cause embarrassment or other unwanted social fears for the child (ASHA, 2002). Other limitations of both systems include outside interference due to similar frequency ranges such as powerful pager systems or FM radio transmissions (Lewis, 1994b). Despite a few drawbacks associated with the personal or self-contained FM systems, the overall positive benefits of an increased SNR has been well documented for individuals with hearing loss, fluctuating hearing loss, and those with normal hearing who have disorders with attention, learning, or English as a second language (ASHA, 2002).

Induction loop FM system. A second type of wireless FM system is called the induction loop FM system. The induction loop system consists of a wireless microphone, amplifier, and a wire loop that is installed around the listening area, such as under the carpet or around the perimeter of the room. The receiver is either a telecoil-equipped hearing aid or and induction receiver. The wireless microphone picks up the speakers voice and transmits it via FM radio waves that create an electrical current through the wire loop. This produces an electromagnetic signal that can be received by the telecoil in the hearing aid or an induction loop receiver.

Induction loop amplification systems are not commonly found in classrooms but rather in other large group gathering areas like courtrooms or church assemblies. Benefits of using these types of systems in a classroom might include not having to purchase an additional receiver since a hearing aid with a telecoil would function as a receiver. Furthermore, these systems are easy to use and maintain and can be used for a variety of hearing losses. Limitations to the loop system include restricted mobility of the speaker to the area within the loop and lack of portability for the listener. Once outside the loop, the amplification performance significantly plunges. Also the orientation of the hearing aid with the wire loop in either the horizontal or vertical plane can impact the amount of amplification received. Additionally, electromagnetic interference can be problematic. For instance, televisions, fluorescent lights, and steel structures produce magnetic fields that can disrupt the amplification. Other performance factors to consider are the size of the telecoil, the presence of a telecoil preamplifier to boost the telecoil sensitivity, and the telecoil orientation within the hearing aid (Lewis, 1994a).

Infrared FM systems. A third type of wireless system is the infrared FM system. An infrared system is similar to other FM systems except the signal is transmitted by infrared light waves. Specifically, the acoustic signal is converted into an infrared light bean by an emitter and a specialized receiver picks up the signal and converts it back to an audio signal. These systems are often used in large theater settings or for home use with the television. An advantage to using this system is that the signal is not able to pass through walls, which prevents the signal from spilling over to adjacent classrooms and preserves confidentiality. Other advantages of infrared technology include the use of multiple infrared FM systems (i.e., several individuals may wear an infrared receiver and hear the speaker), ease of installation, and no size limitation to the emitter panels. Disadvantages include the costly need for a receiver for each user; interference from florescent lights and natural sunlight; the infrared pathway must be essentially unobstructed and lack of portability (Lewis, 1994a).

Sound field amplification (SFA) systems. A SFA system consists of a microphone, amplifier, and loudspeakers, which are placed strategically around the classroom. Generally, there are two loudspeakers in the back of the classroom and one near the front for the entire class to hear (Tye-Murrary, 2009). This technology allows all the students to hear the teachers' voice regardless of the distance or location of the teacher in the classroom (Berg et al., 1996; Dockrell & Shield, 2012). A smaller type of SFA is the desktop SFA system. In this case, a speaker unit is placed on the child's desk instead of around the room, but works in the same fashion as the classroom SFA. Furthermore, SFA systems aim to provide a SNR of approximately 10-15 dB above the noise floor throughout the classroom. For that reason many researchers and clinicians have supported the use of SFA systems in classrooms for children with hearing impairment, normal hearing, and those at risk of other learning and developmental disabilities (Anderson & Goldstein, 2004; Berg et al., 1996; Dockrell & Shield, 2012).

Several positive benefits of the SFA system have been identified. The biggest benefit is the overall improved signal for everyone in the classroom regardless of hearing status. This is especially beneficial due to the high incidence of fluctuating otitis media in younger school aged children. Furthermore, since children with hearing loss do not have to wear any extra equipment, social and emotional stigmatization is reduced when SFA is used. There is also no further cooperation needed from the students to receive the amplification. SFA systems are relatively easy to use and require little to no maintenance or troubleshooting for the teacher/school personnel. SFA systems are also viewed as cost effective since all students can benefit with the cost of purchasing one SFA unit verses a receiver unit for each student. Some of the disadvantages include lack of portability. For instance, each classroom must have its own system installed. Another limitation concerns the placement of the loudspeakers. Due to a variety of classroom sizes, shapes and arrangements, the loudspeakers must be installed optimally to avoid introducing distortion. Lastly, SFA alone does not provide sufficient amplification for those with more than a mild degree of hearing loss (Lewis, 1994b).

Benefits of SFA. Many studies have been conducted to investigate the benefits of the various types of FM systems. Furthermore, several studies have documented the positive effectives of SFA in overcoming poor classroom acoustics. For example, SFA has the ability to reduced background noise, reverberation, improve academic performance, as well as reduce teacher vocal strain (Wilson et al., 2011).

Anderson and Goldstein (2004) performed one such study to examine the effectiveness of three different classroom amplification technologies: desktop sound field FM, personal FM, and ceiling infrared sound field FM. Specifically, this study had three purposes to evaluate. The first purpose was to assess the speech recognition abilities under typical classroom noise and reverberation conditions for children who had hearing loss and used hearing aids. Secondly, using the same children, speech recognition abilities were tested with the three FM technologies. Lastly, participant and parental opinions on the three FM conditions were assessed.

Participants included eight children ranging from 8 to 12 years-old who had congenital hearing loss of mild to severe degree or normal lows with mild to severe hearing loss above 1000 Hz. Secondly, the participants had aided speech recognition thresholds that were within normal to mild hearing loss range. This experiment took place in a kindergarten classroom. Phonak Novo Forte 3 hearing aids were connected via DAI to Phonak MicroLink ML7 personal FM receivers in seven of the eight subjects. Subject 4 had personal Widex C19 digital hearing aids that were paired with the MLX FM receivers. Amplification systems used in the experiment are as follows: (1) TeachLogics IR-2500 infrared sound field system with two speakers adjacent to the ceiling, (2) LES 390 Desktop SoundPak by LightSpeed Technologies, and (3) Phonak MicroLink ML7 ear-level receiver and an ML7 transmitter. The Hearing in Noise Test (HINT) was used as the speech stimuli under each of the three amplification conditions. The experimental design was conducted under controlled conditions to represent a typical kindergarten classroom for each of the three types of amplification tested. For the background noise, a recording of hospital cafeteria noise was presented at a constant 60 dBA noise level while that HINT list was presented with +10 dB SNR, and reverberation was recorded at 1.1s. Social validation was assessed though questionnaires for the participant and their parent(s).

Results of the subjective loudness assessment for each type of FM technology (i.e., hearing aids only, infrared SFA, desktop FM, and personal FM) were rated based on perceived intensity levels from lowest to greatest levels. Hearing aids only was rated as the least loud followed by personal FM, classroom SFA, and desktop sound field as the loudest. Next, word recognition performance was examined under each experimental condition. Of the eight participants, four exhibited high levels of accuracy with hearing aids only, thus leaving minimal room for improvement. Although, an increase in the percent correct was noticed for the majority of the participants, no significant difference was found between the uses of the ceiling infrared SFA or hearing aids alone. Both the desktop sound field and personal FM system showed benefits over hearing aids alone. These results were maintained across replication trials indicating the test conditions were reliable. Lastly, social validation was examined to identify the preferences by the participants and parents. The desktop or personal FM systems were chosen by six out of the eights participants as the preferred device. One child chose the ceiling sound field system and one child selected the personal FM. Results of the parents responses to social validation was obtained for seven out of the eight participants (speech perception was not observed for Participant 3).The investigators found six of the seven parents were in agreement with the child's preference on the device that provided the greatest ease of listening.

Based on these results, Anderson and Goldstein (2004) concluded that in a noisy reverberant classroom children with mild to moderately-severe degrees of hearing loss showed no substantial benefits with the use of the infrared sound field systems as compared to hearing aid only condition. However, increased speech perception was found as well as a social preference to using either the desktop sound field or personal FM system in conjunction with hearing aids. From the results, they concluded that those students in a noisy, reverberant setting either personal for
FM or desktop sound field systems provided measurable listening benefit.

A study by Wilson et al. (2011) evaluated if SFA devices influenced student performance in three dissimilar classroom environments (i.e., [1] classrooms in a brick building with neighboring rooms separated by solid walls [School 1], [2] classrooms in a brick building separated by open space [Schools 2 and 3], and [3] demountable buildings, separated from other classrooms by a solid wall [School 4]). The research design included pre- and post-assessments on the test subjects in classrooms with SFA devices as well as a control group in a classroom without SFA devices. Participants were from four primary public schools, School 1- completely brick; School 2 and School 3 were brick with an open, nonseparated classroom; and School 4- demountable building, all within the same school district in Australia, totaling 147 students.

The SFA devices (i.e., single-speaker Redcat devices with a Lightmic microphone) were used in the classrooms for 16-18 weeks. The assessment battery included The Literacy and Listening Index (LLI; Weedon & Reid, 2000) which consist of several subtest of listening (LLI-Listening), spelling regular words (LLI-Regular Word Spelling), spelling sight words (LLI-Sight Word Spelling), and reading comprehension (LLI- Reading Comprehension). Other assessments included the Test of Auditory Analysis (TAAS; Rosner, 1979) and the Listening Inventory for Education: Student Appraisal of Listening Difficulty (LIFE-SALD; Anderson & Smaldino, 1998). Further details of each test assessment can be found in Wilson et al. (2011).

Measures of classroom acoustics were obtained with a sound level meter. Background and RT measurements were completed using the ANSI S12.60-2002 protocol. Pre-treatment range scores and median scores were obtained in the test group and control group. The LLI subtest and the TAAS scores were close to the maximum scores for many of the test subjects. Furthermore, there was no significant difference between the test and control groups for any of the pre-tests used. Post-treatment median and range scores of the schools revealed significant differences between the school's test classrooms. For the TAAS, School 1- brick, which was separated from neighbors by a brick wall, was higher for test classroom than School 3- brick non-separated. On the LIFE-SALD, School 3 and 4 had higher scores than School 2. School 3 showed higher TAAS scores in the control than its matched test classroom. Results also showed School 1 with higher LLI-Listening subtest and TAAS scores than the control classroom. An evaluation of an estimated 1-hr, A-weighted background noise levels and RTs of the schools revealed that School 1 had the lowest background noise level followed by School 2, 3, and then School 4 with the highest level. RTs in test and control classrooms were lowest in School 4 followed by School 1, then School 2 and 3.

Behavioral data seemed to suggest that only the test classroom of School 1 showed benefit with SFA in areas of auditory analysis and listening. Furthermore, School 1's classrooms, located in a brick building with a solid wall separating them from neighboring classrooms, had the second lowest RTs and lowest background noise levels. Contrary to commonly reported benefits of SFA devices, this study found that SFA devices only promoted skills in the areas of auditory analysis and listening. Based on these results, Wilson et al. (2011) found that SFA devices are more likely to provide benefit for students in classrooms that proximate the acoustical recommendations set by ANSI S12.60-2002. Wilson et al. (2011) further demonstrated the value of appropriate classroom acoustic as it pertains to student performance with the use of SFA.

The benefits of SFA has been well documented in improving classroom acoustics, however researches has also documented the benefit of SFA in areas of academic achievement for individuals with a hearing loss and those with normal hearing sensitivity. One such study, conducted by Langlan et al. (2009) aimed to investigate if the use of SFA had a direct effect on the students' classroom performance. They examined students with and without hearing loss, focusing on conductive hearing loss (CHL). This study examined three objectives. The first was to observe if there was a change in the students' classroom performance during treatment with SFA and post-treatment, after amplification. The second objective was to evaluate if scores with SFA differ for students with hearing loss verses those with normal hearing. For the third objective, they measured the teachers' impression of SFA use.

The participants for the study consisted of 40 students, from Grade Primary to Grade 6; the mean age was 7.75 years (range = five to 11 years). The Screening Instrument for Targeting Educational Risk (SIFTER; Anderson, 1989) questionnaire was completed based on teacher's observation of each student's classroom performance. The SIFTER uses a five point scale to rate areas of academics, attention, communication, class participation, and school behavior. The procedures employed in the study included an ABA experimental design, (A = pre-treatment, B = sound field treatment, A = post-treatment). Over a seven month period, data from the SIFTER was obtained for the 40 participants at the end of each month. The pre-treatment SIFTERs were obtained during the two months before the use of SFA as a baseline. The treatment SIFTERs were collected during the three months with the use of SFA. Lastly, the post-treatment data were collected two months after the SFA system was turned off.

Furthermore, to determine hearing status, two hearing screenings were conducted. The first hearing screening was performed two months before the SIFTERs were completed, and the second was in April during the use of SFA treatment. The purpose of the hearing screening was to evaluate which students had hearing loss during the SFA treatment period. Then, children were grouped according to whether they had normal hearing sensitivity at both screenings (N = 26), those who were identified with hearing loss in only one screening (N = 10), or those identified with hearing loss in both screenings (N = 4). The students with normal hearing were assumed to have normal hearing throughout the treatment period. Likewise, the group identified with hearing loss by both screenings was presumed to have a hearing loss during the treatment observation. The group of students identified by only one of the screenings with a hearing loss was suspected to have suffered from a fluctuating hearing loss during the SFA treatment period. Lastly at the end of the study, teachers were asked to complete a 10 question survey regarding the teachers' impression of the use of SFA.

The mean pre-treatment, treatment and post-treatment SIFTER showed a significant two-way interaction between the SIFTER content area scores and treatment conditions. From pre-treatment to the treatment conditions of the SIFTER, all areas showed improvement with attention having the largest increase. Each SIFTER area showed a mean decrease in the post-treatment condition (i.e., two months after SFA was off) with the SIFTER areas of attention and academics having the largest decrease in mean scores from the treatment to post-treatment conditions. Next, they investigated the performance scores with children with normal hearing and hearing loss. The children identified with hearing loss showed the greatest percentage of students (75%) that improved in mean SIFTER scores from the pre-treatment to treatment conditions and decreased from treatment to post-treatment condition. All groups showed greater mean scores during the treatment conditions compared to the other two conditions. Furthermore, the normal hearing group revealed the highest mean SIFTER scores followed by those identified in one hearing screening. Those identified with hearing loss in both screenings showed the lowest scores in each treatment condition and demonstrated the largest decrease in scores during the post-treatment condition. Results from the teacher questionnaire showed that all teachers in the study reported benefits from the use of SFA and overall acceptance of using SFA.

Langlan et al. (2009) demonstrated that all of the students in the study showed significant improvements in areas of academics, attention, communication, class participation, and school behavior with the use of the SFA system. However, once amplification was discontinued, student performance was not sustained, indicating that the improvements only occurred during the actual use SFA. Furthermore, students with hearing loss, as well as those possibly suffering from fluctuating otitis media, were shown to greatly benefit from the use of SFA. In addition, results from the teachers' survey were consistent with other findings of teacher satisfaction with SFA. Teacher reported benefits included less vocal strain, a general feeling that their students understood them better, and that the students' benefited from the SFA system.

Similarly, a three year FM sound field study called the Improving Classroom Acoustics project (ICA) was carried out in two phases by Rosenberg et al. (1999) to investigate if the use of SFA improved students' listening and learning behaviors. This experiment aimed to overcome some of the limitations in a previous study carried out by the Florida Department of Education to evaluate the effectiveness of SFA.

This study involved a total of 2,054 students in 94 general education classrooms. Phase I consisted of two groups of students. The first group from Phase I included 1,319 participants from kindergarten, first, and second graders that were divided into 30 control groups who were placed in unamplified classrooms and 30 experimental groups who were placed in classrooms with SFA. This group was observed for 12 weeks. The second sub-group in Phase I consisted of 804 students (20 control and 20 experimental classrooms) who were observed for 30 weeks to investigate change over a longer period of time. Phase I consisted of a total of 60 teachers that were provided with a four hour in-service training covering topics such as classroom acoustic, speech perception, strategies for improving listening and learning behaviors, and use of SFA system. Phase I conducted pre-, mid- and post- treatment observation in each group. Phase II, which included SFA in all classrooms, consisted of 735 kindergarteners, first graders, and second graders enrolled in 19 schools in Florida. The duration of Phase II was four weeks and consisted of pre- and post-amplification observations of the classrooms. Phase II involved 50 teachers who also received similar in-service training as Phase I. Hearing screenings were conducted for 1,252 students in Phase I, but none were performed for Phase II due to insufficient resources.

Teachers in both Phases of the experiment completed a classroom environment worksheet, *ICA Classroom Description Worksheet* (Florida Department of Education, 1995), regarding classroom acoustics, noise levels, and other pertinent classroom information. Phase I included noise measurement data which consisted of measuring unoccupied and occupied classroom noise levels as well as teachers' vocal intensities. In all experimental classrooms, the Phonic Ear Easy Listener Free Field Sound System with a four speaker arrangements was installed. Furthermore, two teacher rated surveys were used, The *Listening and Learning Observation* (*LLO;* FDE, 1995a) which assesses listening, academic /pre-academic behaviors and skills and the *Evaluation of Classroom Listening Behaviors (ECLB;* VanDyke, 1985), which rates classroom listening behaviors.

The LLO use a five point scale that teachers used to rate the students' behaviors and skills, where 1 = below average and 5 = above average. The ECLB consisted of 10 items that teachers used to rate the listening behaviors of the classroom. The ECLB also used a five point rating scale where 1 = seldom and 5 = frequently. During Phase I, the LLO was used for all students, and the ECLB was used for 10 students who were randomly selected in each class. Student observations were completed three times, pre-treatment, mid-treatment, and post-treatment for the 12 week observation group. For those students in the 30 week period, additional observations were completed by the teachers at 21 weeks and 30 weeks. In Phase II, teachers completed both LLO and the ECLB for each student. Phase II was four weeks long and consisted of pre-treatment and post- treatment observations. During both phases of the study, students, teachers, parents, and school administrators completed a survey evaluating the use of SFA system. These evaluations were completed at the end of the 12 weeks for both of the groups examined in Phase I. In Phase II these evaluating were competed at the conclusion of four weeks.

Results of the Phase I project for students and treatment group showed no significant difference between treatment groups for any of the effects. Results from the hearing screening performed on 1,258 students from Phase I revealed a pass for 74.88% at 15dB and a pass for 94.36% at 20 dB HL. A tympanometry screening of 1,252 students found 92.57% had normal tympanometry results. Measurements of classroom ambient noise levels from Phase I found that two of the 60 classrooms met the 35 dBA acceptable acoustical standard for unoccupied classroom. Results revealed the unoccupied classroom mean was 47.48 dBA with the unoccupied kindergarten classes measuring the quietest at a mean of 46.40 dBA and the loudest was the unoccupied first grade with a mean of

48.50 dBA. Measurements of the occupied classrooms had a mean noise level of 62.63 dBA. The occupied second grade classes were the quietest at mean level of 60.76 dBA and the noisiest classes were the occupied kindergarten with a mean level of 65.20 dBA. Acoustical treatments were investigated in Phase I, and 91.7% of the classrooms had acoustical tile ceilings, 86.7 % had carpeting, 25% had carpeting installed over padding, 10% had draperies, and 53.3% had blinds. Phase I investigating of the teachers' voice intensities with the use of SFA found an average increase of + 6.94 dBA in vocal output. The LLO analysis for Phase I showed greater significant improvements in listening and learning behaviors and skills at a faster rate in the treatment group with SFA than the unamplified control group. Specifically, the LLO showed the experimental group to be significantly different from the control group for pre-treatment to mid-treatment, mid-treatment to post-treatment, and pre-treatment to post-treatment.

In Phase II results for the LLO and ECLB identified significant changes in mean score after four weeks of SFA. Next, they conducted an evaluation of which grade level and treatment groups had the greatest and least amount of improvement for both test phases on the LLO and ECLB measures. In Phase I, the amplified group of first graders had the greatest improvement in LLO total score at 6 weeks and 12 weeks observations. The control (unamplified) kindergarten students demonstrated the least amount of improvement at the same observation time. Further analysis of each treatment group (with SFA) showed significantly higher scores on the LLO and ECLB. The ECLB analysis revealed similar results for Phase I. The greatest improvement was seen for kindergarten students with SFA and the least improvement was seen for first and second graders in the control classrooms. For Phase II, second graders showed the least improvement while first graders showed the greatest improvement in LLO and ECLB scores. Then an analysis was performed on the data collected for the 30 week observation group of Phase I. Phase I mean observation scores of the LLO and ECLB taken over a 30 week period (at 6 ,12 , 21, and 30 weeks) were significantly higher for the experiment group than the control group. Surveys completed by students, teachers, parents, and school administrators showed an overall positive support and perception for the use of SFA bases on perceived benefits.

In summary, Rosenberg et al. (1999) demonstrated that significant improvements in listening and learning behaviors could be achieved with the use of SFA. Furthermore, they showed that this improvement progressed at an increased rate when compared to grade matched peers in unamplified classrooms. They found that the greatest improvement occurred with the younger students in an amplified classroom providing additional support for the use and the benefits for SFA. Their study also supported that classroom acoustic treatments and the unoccupied noise level have not change from previous studies over the past 20 years. The students, parents, and administrators provided an overall positive evaluation of SFA. Research from this study supports the use of SFA to enhance the listening and learning conditions of the classroom.

Furthermore, Darai (2000) investigated the impact SFA had on literacy scores of first-grade students. Hearing plays a significant role for learning to read and basic reading skills emerge during the first-grade. Therefore, the purpose of this research was to examine the connection between classroom amplification and literacy outcomes. Participants were from eight 1st grade classrooms. Of the 166 first-graders, there were 88 students in four experimental classrooms with SFA and 81students in four control classrooms without SFA. The SFA systems consisted of a box receiver, transmitter, boom microphone, and four speakers installed according to manufacture instructions. Teachers in the four experimental classrooms were educated on the use of the SFA systems and instructed to maintain their usual teaching style while using SFA. An Informal Reading Inventory (IRI) was used to evaluate literacy achievement growth at the middle and end of the year (Darai, 2000). The Listening Inventory for Education (LIFE; Anderson & Smaldino, 1998) from the Teacher Appraisal of Listening Difficulty inventory was used to measure changes in attention, classroom participation, and learning as a result of classroom acoustic intervention. Four teachers from the experimental classrooms completed the LIFE at the conclusion of the study.

Data from the on the IRI literacy assessment showed a significant difference between the experimental classrooms with SFA, which showed greater literacy gains, than the control classrooms. Although, literacy growth of one to two reading levels was seen for students in both the experimental (32 out of 85) and control groups (38 out of 81), a significantly greater number of students in the experimental group (28 out of 85) showed more growth in achievement as compared to students in the control group (13 out of 81). Though the sample size was small for special education, bilingual and hearing impaired students, the results showed substantial increase of literacy performance for these students in the amplified classrooms. Analysis of the LIFE appraisal form showed large approval ratings for the use of SFA to improve classroom acoustics. Teachers reported that the improved acoustics with SFA also helped to facilitated language and phonics instruction as well reduce teacher vocal strain. The teachers in the experimental classroom reported that the students were more attentive, and all teachers in the experimental classrooms rated the SFA as "highly beneficial." Anecdotal reporting from both students and teachers from the experimental classrooms confirmed their preference for listening and learning in an amplified classroom. Based on these results, Darai (2000) concluded that first-grade students in amplified classrooms were able to achieve significantly higher gains in literacy compared to those in the control group without SFA. This research highlights the importance of using SFA as a method of improving classroom acoustics and enhancing the listening and leaning environment as well as improving the teacher's vocal strain.

Likewise, Flexer, Biley, Hinkley, Harkema, and Holcomb (2002) conducted a study using SFA to teach phonemic awareness to preschoolers. They proposed that the use of SFA in preschool and kindergarten would improve the acoustic environment and help facilitated the development of early phonological and phonemic awareness (pre-literacy skills) and thus enhance future reading success. Specifically, this study investigated if early phonological and phonemic awareness training with the use of SFA would decrease the number of children identified by the Yopp-Singer Test of Phonemic Segmentation as at-risk readers (Yopp, 1995). Participants for the study included 53 students from three pre-school classrooms for 4-year-olds; the children were followed for one year, beginning in the second semester of pre-school and continuing to the end of the first semester of kindergarten. Three pre-school teachers and three kindergarten teachers were involved in the study. Participants were divided into three groups: Group A, B, or C. Each group received a particular early phonological and phonemic awareness intervention program and this program was maintained as the group of students progressed to kindergarten. Group A was the control group and received the school district's standard preschool and kindergarten curriculum. Teachers in Groups B and C attended three in-services on phonological and phonemic intervention strategies and agreed to incorporate these strategies in the daily teaching curriculum for 15 minutes, four times a week. Group C attended two additional in-services on classroom acoustics and classroom amplification systems and agreed to also include the daily use of SFA. Two SFA systems (Ultimate Infrared four-loudspeaker units from Audio Enhancement) were used. One was installed in Group C's pre-school classroom and one in Group C's kindergarten classroom. The systems included a wireless microphone transmitter worn by the teacher, an amplifier/transmitter connected to four loudspeakers placed around the room in accordance to manufacture instructions, and a pass-around microphone for the students to use. The Yopp-Singer Test of Phonemic Segmentation was used to measure a child's ability to sound out spoken words by articulating the sounds in order. This test was administered in preschool as a baseline measure and then again at the end of the first semester in kindergarten as a post-test measure.

The investigators first looked at the difference between the pre- and post-test scores. Non-parametric procedures were used to prevent skewing of the data due to unexpected low enrollment in the Group B kindergarten class (7 subjects). The pre- and post-test scores showed a statistically significant difference among the scores for the three Groups evaluated. Post-hoc test results showed significantly higher scores for Groups B and C than the control, Group A. A general trend in the distribution of the results showed an increase in scores with the phonological and phonemic awareness training and a further increase when SFA was added. Furthermore, a second variable of the Yopp-Singer Test identified those who were at-risk for developing reading problems.

In Group A, the control group, 13 students (57%) were identified as at-risk; in Group B (intervention only group) 3 students (43%) scored at-risk. Lastly, in Group C (intervention with SFA) only 2 students (9%) scored at-risk. Based on these results, Flexer et al. (2002) concluded that the use of phonological and phonemic training seemed more effective when SFA was used. Providing SFA along with phonemic awareness training resulted in a more positive impact on literacy skills taught in preschool and kindergarten classrooms.

Similarly, Purcell and Millett (2010) examined the effects of SFA on reading outcomes for Canadian Grade one students lasting one school year. There were four research questions they sought to address. First, they asked if students in amplified classrooms were able to achieve increased levels of difficulty in reading scores compared to those in unamplified classrooms. Secondly, they looked at what percentage of students in the amplified classrooms was able to read at or above grade level. Next, they examined if there was any interaction between gender and SFA reading outcomes. Lastly, they examined if students identified as at-risk readers showed improvements with SFA. Participants included in the study were from 24 Grade one (i.e., first grade) classrooms within the Ontario, Canadian school board district. The study took place during the 2002-2003 school year and included 486 students.

This study was conducted with a quasi-experimental design with 12 classrooms as the experimental group (with SFA) and 12 classrooms as the control group (without amplification). The Phonic Ear VocaLight infrared SFA systems were installed by employees contracted by Phonic Ear. All teachers were provided with an in-service on the SFA systems. These systems consisted of teacher-worn transmitter, infrared sensor and receivers, and four wall-mounted speakers. A hearing screening was conducted in September. The reading assessment was conducted with the first edition of the Developmental Reading Assessment (DRA; Beaver, 1999). The DRA was already required by the school board to be administered in September, January, and May. For the purpose of this study, data from the DRA was used to report the number of reading level change from September to May and the percentage of students reading a "below," "at," or "above" grade level in both terms. Only the teachers using the SFA systems were also administered the Teacher Opinion and Observation List and Voice Subsection of the Listening Inventory for Education (Anderson & Smaldino, 1998). This questionnaire used a five item Likert scale from "strongly agree" to "strongly disagree" and 11 of the 12 teachers who used SFA in their classroom completed the inventory. The demographic information showed that both the control and experimental classrooms were similar in respect to number of students, gender distribution, number of students with an Individualized Educational Plan (IEP), number of students whose hearing was screened, and number of students receiving Early Reading Intervention (ERI) as a result of being identified as at risk for reading in kindergarten.

The mean increase in reading levels between the experimental and control group from September to May showed no significant difference. However, it was noted that the DRA book level progression did not represent equal intervals. For example, Purcell and Millett (2010) state, "moving from Level 1 to Level 3 does not represent either quantitatively or qualitatively the same change in reading competency and skill as does moving from Level 18 to Level 20 book" (p. 21).

Next, they investigated if students in the amplified classroom showed a greater change in reading at grade level than the unamplified group; they found no statistical difference. Unfortunately a post hoc power analysis revealed that the sample size of the study did not have sufficient power to detect intervention effect size. The authors suggested that the experiment procedure used may have not been sensitive enough to the effects of SFA or that the study duration was not long enough. However, there was a trend revealing a greater percentage of students reading at grade level in the amplified classroom than the unamplified.

Thirdly, they investigated whether an interaction between gender and amplification was present. A significant main effect for gender was identified, with a larger percentage of girls reading at grade level than boys. There was no main effect found for amplification or an interaction effect between amplification and gender. Lastly, the fourth research question they addressed asked if students identified as "at-risk" for reading showed a change in reading scores with SFA. There was a main effect for student "at-risk" and receiving ERI, but no other statistical significant was found. Again, several trends were noted. The pre-test revealed that 27.7% of the students in the amplified classroom were reading at grade level, and in May (post-test) the percentage had increased by 5.3%. The control group had 37.8% reading at grade level in September and decreased by 6.7% in May. The teacher assessments indicated that their experience with SFA was "extremely positive." They found that 100% of the teachers experienced less vocal strain and all teachers reported liking the overall impact on their teaching voice and presentation. Response from teachers were averaged and teachers reported to show the strongest agreement regarding the following statements: less need for repetition, less need for clarification, and less need or time spent in classroom management.

Based on the above results, Purcell and Millett (2010) concluded that although statistical significance was not found, trends were noted showing a greater increase in the percentage of Grade one students reading at grade level at the end of the year with SFA verses the unamplified classrooms. Also, students identified as "at-risk" and receiving ERI showed greater improvements in the amplified classrooms when compared to the unamplified classrooms. Lastly, they concluded that the overall teacher ratings of SFA systems were extremely positive.

Furthermore, Mendel, Roberts, and Walton (2003) conducted a two year longitudinal study to examine the effect of SFA on speech perception benefits. They compared the speech perception performance of young children with normal hearing who were exposed to SFA to similarly matched children with normal hearing who did not use SFA. This study included a total of 128 kindergarten students with normal hearing, speech, and language. The students were randomly placed into six classrooms. The treatment group consisted of 64 students divided into three classrooms with SFA systems while the control group of 64 students was formed from the three remaining classrooms that did not have SFA. The students were followed for two academic years from kindergarten (2000-2001) to first grade (2001-2002). Once the participants entered the first grade, they were placed in eight classrooms; the treatment group consisted of 47 first graders placed in four classrooms receiving SFA, and the control group consisted of four classrooms with 48 participants without SFA. The students remained in the same group as they moved from kindergarten to first grade. At the end of first grade, 95 children completed the study and data from the students (47 students in treatment group and 48 students in the control group) were analyzed. Of the 14 teachers in the study, 7 taught in with the use of SFA and 7 were placed in the control classrooms (i.e., without SFA). The teachers in the classrooms with SFA were provided with an in-service training on SFA systems by an audiologist.

Speech perception was measured using the recorded Phonetically Balanced Kindergarten (PB-K) word list and Word Intelligibility by Picture Identification (WIPI) test. Classroom noise was recorded for 15 minutes from each of the six kindergarten classrooms throughout the day to obtain a representation of the typical classroom sound sample. The Easy Listener Sound Field System by Phonic Ear was installed in the treatment classrooms. The system contained four loudspeakers placed around the room, a microphone/transmitter, and receiver. Other equipment used in the study included a sound level meter (Model 1800, Quest Technologies, INC, Oconomowoc, WI), an Onkyo CD player (Model CDPC900) routed to a Beltone 2000 audiometer or Sonly CD player (Model CDP-CE245) routed to a Grason-Stadler (GSI-16) clinical audiometer with supra-aural headphones. The procedures consisted of testing both the control and treatment groups at three different times: (1) Kindergarten-fall, beginning of year, (2) Kindergarten-end of year, spring, (3) first grade-end of year, spring.

Acoustic measurements were also taken in all classrooms with and without children in the room. PB-K testing was performed in two separate quiet classrooms with an average ambient noise level of 38.6 dBA. Speech perception measurement protocol included one randomly selected 50-item PB-K list administered individually to students via supra-aural headphones with the speech presented binaurally at 56 dB HL and a +6

SNR. To evaluated group performance, the WIPI was accompanied by recorded classroom background noise and was administered to each classroom body; speech stimuli were presented at 70 dBA with SNR of +6 dB. The treatment classrooms presented two different list of the WIPI. One list was though the SFA system and the other was presented without using amplification. In the control classrooms, one WIPI list was presented without using the SFA. All students were given a copy of the WIPI book and were asked to circle the word that they heard. At the end of the study, teacher questionnaires were given to all who used the SFA in their classrooms.

The acoustic measurements for SNRs ranged from +6 to +10 dB in the treatment classroom. The mean sound levels for both the kindergarten and first grade treatment and control classrooms with no students present ranged from 36.66 to 39.51 dBA. When children were present in the classrooms the range was 56.97 to 61.28 dBA. Statistical measurements revealed significantly higher sound levels in both grades when children were present. Reverberation times were also calculated. The value was 0.83s for the kindergarten classrooms and ranged from 0.85 to 0.87s for first grade classrooms. Comparison of control and treatment classrooms did not reveal a significant difference; however, reverberation times in first grade classrooms were significantly higher than the kindergarten classrooms. Furthermore, both kindergarten and first grade classroom ambient sound levels and reverberation times exceed the standards recommended by ANSI S12.60. Secondly, results for the WIPI speech perception test performed in noise without the use of SFA revealed a main effect for both group and test session. Additionally, the results of the mean WIPI scores with the use of SFA revealed a significant main effect for the use of SFA. Specifically, the mean WIPI scores obtained with the use of SFA for each of the three test secession were significantly higher than those obtained without SFA. When all sessions were combined, again results were significantly higher with the use of SFA. Furthermore, a post hoc pairwise comparisons showed significantly higher (better) WIPI scores in the treatment group with SFA than in the control group (without SFA) for kindergarten-Fall and kindergarten-Spring but not for first grade-spring. Thirdly, test results of the mean percent correct performance of the PB-K test in noise for the all students in the treatment and control groups were analyzed and a significant main effect for test session was identified. Post hoc pairwise comparisons showed significantly higher scores for first grade-spring than those obtained in previous sessions (kindergarten-fall and kindergarten-spring). Lastly, they examined the teacher questionnaires that were completed by all teachers who taught in the treatment classrooms with SFA. Mendel et al. (2003) found that 95% of the teachers responded positively to the survey indicating overall support for the use of SFA in the classrooms. Specifically, the teachers reported positive benefits for the use of SFA for the students and themselves, and majority agreed with the statement that using the SFA systems was enjoyable for the teachers and students.

Based on these results, Mendel et al. (2003) concluded that SFA is a valuable contributor to speech perception performance for young children. At the beginning of the study the children demonstrated significant improvements in speech recognition when SFA was use compared to when it was not used. They suggest that long-term exposure to SFA may not be necessary for beneficial effects to occur. Improvements for speech perception performance were seen for both the control and treatment group; however, results for the treatment group revealed that students using SFA showed accelerated progress in speech perception abilities in noise when compared to their peers who did not use SFA. The significant difference measured between the treatment and control groups, however, was not present at the end of the study, indicating maturity and time may play a role in measuring speech perception improvements. Furthermore, the overall teacher's ratings for SFA were very favorable for both the teacher's perception and their students.

In a similar study, Massie and Dillon (2006) examined the effects of SFA on the educational goals of reading, writing and numeracy for children in mainstream cross-cultural classrooms. The subjects in the study were from 12 second grade students, with the majority of students from non-English speaking ethnic backgrounds. There were 242 participants (mean age = 6.8). The equipment used for the study included NAL Twin FM SFA Systems (Type 3032). Each SFA system in the classroom encompassed two lapel microphone/transmitters, receiver/amplifier and four loudspeakers mounted at ceiling height in the four corners of each room.

The procedures included a one-on-one in-service training session for each teacher and an informational booklet addressing classroom acoustics, speech perception difficulties, and suggestions for management and practical demonstration of SFA system. A hearing screening was conducted on all participants at the beginning of the school year and repeated on a subset of students (25% with hearing loss) at mid-year and end of the year. A portable audiometer was used to obtain thresholds at 500, 1000, 2000, and 4000 Hz for both ears. Classroom acoustic measurements such as ambient noise levels, RT measurements, and teacher's speech levels were acquired for each of the 12 classrooms both with and without the use of SFA. The educational outcomes were evaluated using a second grade diagnostic net. The diagnostic net is a method of early monitoring and assesses student's development in literacy and numeracy. Specifically, teachers monitor key indicators of reading, writing, and number skills and rate each student's progress in the key areas at the end of first grade, midway through second grade and at end of second grade. There were two experimental conditions of unamplified 'OFF' and amplified 'ON' for the classes 1 to 8. Two of these four classes used on microphone and the other two used two microphones setup. The remaining four classes were in the unamplified 'OFF' condition. For classes 9 to 12, the conditions were altered between single and dual channel transmission for one semester.

The classroom acoustic measurements had a mean RT of 1.5s and a mean ambient noise level of 68 dB with a range from 64 to 72 dB in the occupied classrooms. When measuring the SFA effects on the teacher voice level, they found a range from +4 to +10 dB with a mean of +6 dB. The results for the educational outcomes showed a significant main effect for system 'ON' when comparing the SFA 'OFF' to the SFA 'ON' condition for classes 1 to 8. Next, they investigated if SFA had similar effects for each semester since a mean skill increase was seen across the four test conditions (Semester 1 amplification, Semester 2 amplification, Semester 1 no amplification, and Semester 2 no amplification). Comparable effects in each skill area with overall higher skill increases in the amplified condition were identified. Lastly, in classes 1 to 8 the effect of amplification showed a similar increase across the three subgroups of students with differing language(s) used in the home. The type of language spoken (English, English and other language(s), no English) also did not interact significantly with the skill areas or the effect of amplification. Lastly, for classes 9 to 12 using SFA throughout the school year with two classrooms using one microphone during the first semester and two classrooms using two microphones during first semester, results found no significant effect for number of microphones. However, there was a significant three-way interaction, with two microphones being better than one microphone for number skills. Based on these results, Massie and Dillon (2006) found that the effects of SFA were beneficial for the three skill areas of reading, writing, and numeracy. These beneficial effects were seen for both students with English as a native language and those with English as a second language. Results suggest that the number of microphones had no influence on the benefits of SFA seen in the educational outcomes. These results provide support for the use of SFA to improve the teacher's voice level and enhancing the attainment of literacy and numeracy skills in elementary school.

Standardized Testing

The benefits of SFA has been well studied and documented as noted above in areas of overall academic achievement, speech recognition, literacy, phonological awareness, reading comprehension, listening comprehension, attention and learning behaviors. However, a question concerning SFA that has not received adequate attention is whether the use of SFA will improve standardized test scores. A search of the available literature has resulted in no studies investigating the effects of SFA on standardized test scores. According to the U.S. Department of Education (USDE, 2002), the federal No Child Left Behind (NCLB) Act of 2001 aims to improve the performance of U.S. primary and secondary schools by increasing the standards of accountability at the school, district, and state level. To achieve this goal NCLB aims to utilize nationwide mandated achievement standards or outcome-measures, as measured by standardized achievement test scores, and associated accountability measures. NCLB requires every state to administer annual tests (i.e., standardized test) in core subjects of English language arts (ELA), mathematics, and science and social studies in grades three through eight and at least once in grades 10 through 12. The premise behind NCLB was to increase educational expectations and goals which would subsequently result in higher success for all students. In an effort to make schools more accountable, NCLB requires that the schools meet or show adequate yearly progress (AYP) towards standards of proficiency. Schools must also be in compliance with this law in order to maintain federal and state funding. If progress is not made, the school may face heavy consequences such as federal sanctions, loss of federal funds, and possible school restructuring (Styron & Styron, 2012). Due to the NCLB, standardized testing has become an essential learning assessment tool and indicator of student and school success.

For the purposes of this research, a standardized test is defined in accordance with the requirements in the NCLB law. The NCLB law requires that states set their own challenging academic content and performance standards. Thus, the state develops its own test or adopts a test to give to the students for the purpose of measuring student achievement and then holds the school accountable for improving academic achievement. Furthermore, the states set their own proficiency standards that students must meet on the standardized test. In accordance with the accountability requirements of NCLB, states must ensure that all children are progressing towards the 100% proficiency goal or AYP that the state sets for itself in reading/language arts, and mathematics. This AYP data is reported each year. If the school meets the AYP goals in proficiency, then the NCLB law allows for certain rewards to be given to the schools; however, if the students' performance is lacking rigorous accountability sanctions may be enforced (Yell, Katsiyannas, & Shiner, 2006).

The NCLB legislation created a standards-bases accountability system in education through which high-stakes testing is used as the primary form of measuring school effectiveness and student achievement. The following studies explore the current literature surrounding standardized testing, accountability, and student achievement.

First, Von der Embse and Hasson (2012) examined if test anxiety influenced performance scores on high-stakes state administered test of high school students. Particularly, they investigated if a potential relationship exists on the basis of socioeconomic status and test anxiety. The study included two schools that were considered economically disadvantaged, Calvin High School in an urban setting and Oak Tree High School in a suburban area. Specifically, there were 40 students from the urban school and 35 students from the suburban school in the study. All participants were in the tenth grade taking the high-stakes state-mandated assessment called the Ohio Graduation Test (OGT). The OGT is a standardized test assessment developed in accordance with the NCLB act to evaluate reading, writing, mathematics, science, and social studies. Test anxiety was measured using the Friedben Test Anxiety Score (FTAS) survey which measures three subscales: social derogation, cognitive obstruction, and tenseness (Friedman & Bendas-Jacob, 1997). Social derogation examines the social component of anxiety while cognitive obstruction measures the influence of anxiety on memory and recall of information; the tenseness scale evaluates the physiological symptoms related to test anxiety. Participants from each school completed the FTAS one week before taking the OGT.

Surprisingly, the school setting did not have a significant relation to test anxiety. When evaluating the relationship of test performance and anxiety, they found that students from both schools who scored lower on the OGT had higher anxiety scores on the FTAS, with the strongest negative relationship occurring on the math subtest. Lastly, the researchers examined if test anxiety accounted for variance on OGT performance between schools. Socioeconomic status accounted for more than 40% of variance of the OGT reading performance scores, 53% of the variance on the math scores, 47% of the variance on the social studies scores, and 46% of the variance on the science test. Anxiety accounted for 4% of the variance in reading performance, 15% variance on math test, 9% variance on social studies, and 7% on science scores. Based on these results, Von der Embse and Hasson (2012) concluded that a strong, negative relationship between test anxiety and the OGT achievement scores. The researchers indicated that more efforts should be considered to combat test anxiety, especial in the face of national high-stakes assessment accountability laws enforced by the NCLB Act.

Additionally, Beckman, Messersmith, Shepard, and Cates (2012) investigated the role that ethnicity, poverty, and language may poses for third, fourth, and fifth grade performance on the Nebraska State Accountability Reading Test (NeSA-R). To evaluate ethnicity, they examined if Black, Hispanic, and White students' scores differ on the NeSA-R. Then, they investigated if poverty and language factors influenced performance on the NeSA-R. Archival data from two elementary schools in a Midwestern public school district of Nebraska was analyzed. The study consisted of 347 students from third, fourth, and fifth grades. The poverty status of the students was determined by identifying the students who received free/reduced priced meals. Furthermore, 56.5% of the 347 student population was classified as English Language Learners (ELL) or Limited English Proficiency (LEP) as defined in NCLB federal guidelines. The population data for the poverty and ELL study was obtained from only one school which had sufficient records available. This part of the study was comprised of 197 students in the third, fourth, and fifth grades. In accordance with the NCLB Act, the Nebraska Sate Accountability (NeSA) test was developed as a statewide assessment of Nebraska's academic content standards for writing, reading, mathematics and science in K-12 grade. The NeSA-R test is developed with standards for grades three through eight and grade 11 and tests two specific areas of Language Arts: vocabulary and comprehension.

The results of the study showed that the mean NeSA scores for Hispanic, Black, and White students were not significantly different. Students who are both ELL and receive free and reduced lunch scored significantly lower when compared to students who receive free and reduced lunch alone. Based on these results, Beckman and colleagues (2012) concluded that ethnicity alone was not a predictor of student performance on the NeSA-R assessment; however, they did note that the mean scores were all below proficiency standard level requirement score of 85, and below the averages for the entire state for ethnic minority groups of Nebraska. Their findings indicated that factors such as poverty in combination with ELL were valid indicators of student who would score lower on standardize tests. This suggests that school demographics, poverty, and ELL/LEP status can negatively impact standardized high-stakes test scores, and students of diverse backgrounds should be considered when accountability decisions are being made from the results of the standardized test.

Furthermore, Wheelan and Kesselring (2005) examined the relationship between performance of fourth-grade students on standardized tests and the perceived effectiveness of elementary school faculty groups. First, the investigators assessed if there were any differences in standardized test performance when the teachers perceived the faculty-members as a group to be functioning higher versus lower stages of development. Secondly, they investigated the joint effects of students' performance on standardized tests, and the faculty's perceptions of their group working level against school demographics, including faculty size, rural or urban location, and district poverty level. Participants from the study were from 61 Ohio elementary schools. The faculty group consisted of principals and all the teachers for each school. From 34 schools in an urban location and 27 schools in a rural area, there were 2,245 faculty members that participated in the study. The Group Development Questionnaire (GDQ; Wheelan & Hochberger, 1996) was administered to faculty members. The Group Development Questionnaire is comprised of four scales to assess the work group developmental level. Scale 1 (Stage 1) measures dependency and inclusion. Scale 2 (Stage 2) measures counter dependency and fight while Scale 3 (Stage 3) examines trust and structure, and Scale 4 (Stage 4) measures work. The standardized test scores from the Ohio Fourth Grade Proficiency Test (OFGPT) were used to compare and evaluated student performance. The percentage of fourth-grade students meeting proficiency state standards in citizenship, reading, science, mathematics, and writing was collected from the 61 schools during the year that the Group Development Questionnaire was completed by the faculty members.

The Group Development Questionnaire was analyzed and categorized into a lower level of development (Stage 1 or 2) and a higher level of development (Stage 3 or 4). Thirty-six faculty groups perceived that they functioned at the lower stage of group development while 25 groups reported functioning at the higher level. When analyzing the standardized test scores, they found a significantly higher percentage of students who met the state proficiency standards in citizenship, reading, and science in those schools where the faculty perceived the group to function at a higher level. School and district demographics were also examined. When analyzing staff size, a significant difference was found in schools with 30 or more staff members where 47.2% of the students met proficiency standards in citizenship, and 59.4% met proficiency in citizenship in schools with less than 30 staff members. To further investigate this finding, from the 34 schools with 30 or less faculty members, 18 groups believed they were in the lower level and 16 groups believed they functioned higher. Again, a significant difference was found in citizenship. When the faculty group was perceived to function at a higher stage, 68.3% of the students met the citizenship state proficiency while 51.5% was found in schools where the faculty perceived the group development level to be lower.

When investigating the school with more than 30 staff members, they found 18 of those schools perceived the faculty group to be in lower stages, and nine faculty groups believed they were functioning in higher stages of development. In the schools with more than 30 staff members, the only other significant difference was found in the area of science. In the nine schools which the faculty group perceived itself to function on a higher level, a significantly higher amount of fourth-graders met state proficiency in science. Next, they analyzed rural versus urban school districts. There were no significant findings for reading; however, there were significantly more fourth-graders from the rural locations that were proficient in citizenship, mathematics, writing, and science. The 27 rural schools were further examined, and results found that 13 faculty groups ranked in the lower stages while 14 faculty groups believed they were in the higher stages of development. The only significant difference was found the area of citizenship in which more fourth-graders met proficiency from the 14 schools that perceived the faculty to be functioning at a higher level. Even though no significant differences were found in the four subject areas, it was observed that more students met proficiency in all subject areas in the schools that were functioning in the higher stages of development. When analyzing the urban schools, they found similar results as those in the rural setting. In the schools were the teachers believed the faculty group to function at a higher level, there was a higher percentage of students that met proficiency in citizenship. Also, a higher percentage of students met proficiency in all subjects in the school were the faculty group perceived itself working at a higher level of development.

Lastly, the poverty level was investigated. In the schools classified as low or average-poverty, the results showed significantly more students were proficient on mathematics, reading, and writing than in schools classified as high-poverty. Upon further investigating the high-poverty schools, 15 high-poverty schools believed that the faculty group functioned at the higher stages of group development. From those 15 schools, significantly more students were proficient in mathematics, reading, writing, science, and citizenship.

In conclusion, the authors indicated that not only did the school demographics such as staff size, school location, and poverty level significantly influence student performance, but also the manner in which the faculty members perceived how they worked together as a group influenced students test scores. From the results, Wheelan and Kesselring (2005) suggested that even in similar school demographic profiles, the perceived effectiveness of the faculty group could positively influence students' learning and test assessment performance. Therefore, they recommended more efforts should be developed to focus on improving how the faculty group works together.

Likewise, Lee (2006) investigated the effects of school accountability polices such as an input-guarantee approach and performance-guarantee approach on academic achievement of fourth and eighth-grade students by evaluating standardized test results in reading and mathematics. Since the birth of the NCLB, schools and students are held accountable for their performance as measured by high-stakes standardized test. However, each state can have its own school accountability policy and there is much debate and controversy whether test-driven accountability improves or obstructs academic achievement.

Currently, the two main school policy approaches to accountability are based on input guarantee or performance guarantee approaches. The input guarantee approach ensures the state provides adequate key school resources such as per-pupil spending, class size, and teacher training to improve learning opportunities. In contrast, the performance-guarantee approach relies on outcomes for academic improvement through the use of high-stakes testing. This state policy approach holds schools and teachers accountable for the students' performance and is regulated through financial incentives, mandates, and sanctions.

The methods in this study included measures of State support for school resources by developing a composite factor of averaging three school resources such as per-pupil educational expenditures, average class size, and in-field teaching rate. Schools from 50 states were classified into three resource support groups as follows: 13 states were high support, 25 states were medium support, and 12 states were low support. To measure the pressure for school policy accountability, data from three separate surveys was collected. The data was from: 1) the North Central Regional Education Laboratory and Council of Chief State School Officers (NCREL/CCSSO); 2) the Quality Counts report; 3) the Consortium for Policy Research in Education. The 50 states were then divided into groups of strong accountability systems (12 states), moderate accountability (25 states), and weak accountability (13 states). Data from the National Assessment of Educational Progress was use to analyzed fourth and eighth-grade math and reading state assessment scores. Statistical analysis of the relationships of accountability policies, school resources, and achievement outcomes of reading and math was conducted through correlation and regression measurements.

No relationship between the state test-driving accountability (performance guarantee) and state support for school resources (input guarantee) were found. Next, the effects of the accountability policies and school resources on achievement were examined. Data from the National Assessment of Educational Progress showed improved achievement scores in mathematics for states classified as strong accountability versus those in the weak accountability states. The states' average reading and math achievement was significantly negatively associated with state pressure for school accountably and positively associated with school resources. When examining the growth rate of the average reading and math achievement scores, both fourth and eighth-graders significantly improved across the states. However, only in math was the gain positively related to the states' accountability policies and to the school resources. Lastly, when looking at the interaction between state accountability and support, significantly stronger math achievement gains were seen in states that demonstrated more support for school resources.

Based on these results, Lee (2006) concluded that a relationship between student achievement outcomes and key school resources exists. When performance-guarantee approach is combined with an input-guarantee approach, the result indicated that greater improvements in academics can be made. Thus, to reach the goal of 100% proficiency in math and reading set by NCLB, further research must investigate relationship found between the availability of school resources and the effects of accountability on academic achievement.

***i*LEAP/LEAP Assessments.** The aim of this grant is to obtain SFA systems to conduct future research to investigate the effects of SFA on the Louisiana Educational Assessment Program (LEAP) standardized test. The LEAP test is a series of test that fourth and eighth grade students take each year to determine if they need summer school remediation or be retained. This high stakes test is based on Louisiana's Grade-Level Expectation which measures the students' knowledge and skills in English Language Arts, Mathematics, Science, and Social Studies. The Louisiana Department of Education website (LDOE, 2011) states, "students must score *basic* or above in either English Language Arts or Math and *approaching basic* or above in one other subject."

The *i*LEAP or "integrated" LEAP is a standardized test administered in grades three, five, six, and seven in the state of Louisiana. These tests are congruent with Louisiana's content standards, benchmarks, and Grade-Level Expectations in areas of English Language Arts, Mathematics, Science, and Social Studies. The LEAP and *i*LEAP tests were developed in accordance with the federal educational act, NCLB. The *i*LEAP measures student's progress by comparing norm-referenced and criterion-referenced tests in order to evaluate the performance of the students' results to a national sample and the state's achievement levels. According to the Louisiana Department of Education, the *i*LEAP is not considered a high stakes promotional test like the LEAP; however, it is graded similarly to the LEAP test with achievement levels of *Advanced, Master (Proficient), Basic, Approaching Basic, and Unsatisfactory*. The five achievement levels a student can earn on the LEAP or *i*LEAP are as follows:

- **Advanced:** A student at this level has demonstrated superior performance beyond the level of mastery;
- **Mastery:** A student at this level has demonstrated competency over challenging subject matter and is well prepared for the next level of schooling;
- **Basic:** A student at this level has demonstrated only the fundamental knowledge and skills needed for the next level of schooling;
- **Approaching Basic:** A student at this level has only partially demonstrated the fundamental knowledge and skills needed for the next level of schooling; and
- **Unsatisfactory:** A student at this level has not demonstrated the fundamental knowledge and skills needed for the next level of schooling. (LDOE, 2011)

The LEAP and *i*LEAP scores are used as a direct representation of the school districts' and student's proficiency achievement level (i.e., schools are graded and ranked by how well the students perform on these test each year). Failure to show adequate yearly progress towards the statewide goals results in corrective action and restructuring measures aimed to help the school acquire State standards. Schools that meet or exceed these goals or show improvements in achievement are eligible for State Academic Achievement Awards as well as more flexibility in using Federal Education funds (USDOE, 2002).

With so much attention and focus placed upon state mandated standardized test, additional studies should be conducted to evaluated ways to improved standardized test scores. Therefore the purpose of this dissertation is to write a grant to obtain funding to purchase SFA systems for future research studies.

Chapter III

Request for Proposal Selection

Currently, there is a lack of empirical evidence exploring the relationship of SFA and Federal mandated high-stakes standardized test required by the NCLB law of 2002. The literature review in the previous chapter confirmed that the use of SFA technology is able to overcome poor classroom acoustics and is associated with improved student performance for listeners with normal hearing and those with hearing impairment; improve speech reception ability; and reduced teacher vocal strain to name a few. Therefore, a grant proposal was developed to secure funding for the purpose of obtaining SFA systems to examine the effects of SFA on standardized test scores. The American Hearing Research Foundation regular research grant was the grant chosen. Criteria for the American Hearing Research Foundation grant request for proposal funding includes research that involves hearing or balance functions. The grant allows for basic and clinical studies to be proposed with particular deliberation given to new research. Furthermore, the American Hearing Research Foundation awards four to six $20,000 research grants each year. There were no applicant restrictions provided in the grant application guidelines. All applications are reviewed by the research committee each year and awards begin in January. The American Hearing Research Foundation provides funding for both basic and clinical studies related to hearing or balance. Awarded funds help to expand knowledge in the field of audiology directly related to hearing or balance.

Intended Audience

The award form this proposed grant will be used to purchase SFA systems that will be placed in elementary classrooms to investigate the relationship of SFA and the performance scores on standardized tests. Particularly, the SFA systems will be placed in 3rd and 4th grade classrooms at the beginning of the school year and continue to be used until the end of the school year. This proposed study will include participants from two schools in Lincoln Parish School district in Ruston, Louisiana, that will be administering the *i*LEAP and LEAP standardized tests. From each school, students in a 3rd and 4th grade class will be sampled as test groups (with classroom SFA). A 3rd and 4th grade class without the use of SFA will serve as control groups. Furthermore, an invitation to participate in the study will be sent home with 3rd and 4th grade students. Only the 3rd and 4th grade students who have parental consent will be involved in the data collection.

Measures of Student Performance

Specifically, if awarded, this grant will be used to purchase four SFA systems, which will be placed in two 3rd grade classrooms and two 4th grade classrooms in Lincoln Parish School District (Ruston, LA). Particularly, the SFA systems will be placed in four experimental classrooms (two SFA systems at two different schools) at the beginning of the school year and will be used continually throughout one school year. Additionally, control groups will include a comparison 3rd and 4th grade classroom without the use of SFA from each school. During the month of April, Louisiana students in the 3rd and 4th grade will be assessed by state mandated standardized tests, LEAP and iLEAP. Essentially, standardized test scores from the treatment groups and control groups will be collected and statistical analyzed to determine if students taught with the use of SFA demonstrated a significant improvement in test scores compared to those students who were taught without the use of SFA.

To evaluate the students' performance with and without SFA, LEAP and iLEAP test scores will be obtained from the participating test classrooms and control classrooms. The LEAP and *i*LEAP test scores were chosen because these assessments represent standardized skills that should be obtained at that grade level. Both tests are administered in April during the same week.

Device Selection

Currently the market today is filled with many choices for classroom SFA systems. However several factors lead to the decision to choose the Roger Dynamic Sound Field system by Phonak. The technology in the Phonak Roger Dynamic SoundField system is designed to lessen four problematic issues commonly encountered with traditional SFA: reverberation, feedback, manipulating the systems controls or volume, classrooms with normal and hearing impaired listeners. First, the Roger system uses one or two line sourced loudspeaker units to reduce possible reverberation. Furthermore, feedback often arises when the microphone gets too close to the loudspeaker which restricts the teacher's mobility and often results in reducing the volume. Roger's Dynamic SoundField technology has automated settings that reduce the need for the teacher to adjust the settings and volume on a regular basis as the Roger continually samples the environment and automatically adjusts the frequency response and volume levels. This allows the system to monitor the classroom noise levels as they change and independently make adjustments to further enhance the SNR. This system is designed for classrooms of students who are hearing impaired and have normal hearing by providing three modes functionality that transmits speech in sound field, FM, or both to accommodate all listeners. The speech signal is digitally transmitted and does not require a specific channel. This allows the system to automatically change frequencies to avoid interference with WIFI or Bluetooth networks in the school and prevents dead spots where there is no sound. Furthermore, both the loudspeaker unit and the transmitter microphone have an universal serial bus (USB) port for downloading free internet updates. Other feathers that make this system desirable included the simplicity of pairing the transmitter and loudspeaker, the limitless number of systems that can be used in one site, and compatibility with Whiteboards and other classroom media (Phonak, 2014).

Methods and Procedures

A grant proposal was developed in accordance with the American Hearing Research Foundation guidelines (see Appendix A). The format of the grant proposal contains the following information:

1. Title Page: Include title of project, principal investigator(s), mailing address, phone number, and e-mail address of the individual or institution that is applying for the funding. Be sure this information is on the FIRST page of your proposal. Please state which grant you are applying for: AHRF Grant, Derlacki Grant, Harrison/CORE Grant, or Birtman Grant. Make sure the award you are applying for is being given that year. Please indicate whether you are a Ph.D. or M.D. Be sure to include the name and ALL contact information (including address, phone and e-mail) of the financial officer to whom we should send a check should your proposal receive a grant.
2. Description: Include a brief description of the project.

3. Also include performance site and key personnel.
4. Table of Contents: Include all first-level headings with page numbers.
5. Detailed Budget: Provide a one-year budget (or two-year budget if you are applying for a special grant that spans two years) that includes salary for support staff (students, post-doctorate fellows, etc.), equipment, and supplies. Do not include salaries for principal investigator(s) or overhead; the AHRF does not fund these costs. Your budget should include the total amount asked for (the total) somewhere on the budget page.
6. Biographical Sketch (One for Each Principal Investigator): Please include your contact information (at least phone and e-mail) on the biographical sketch page. List all publications (maximum, two pages), current funding, pending funding, and requested funding. Please indicate what you will do if you receive overlapping funding. Also include letters of support from collaborators, if appropriate.
7. Main Body: Include specific aims of the project; background and significance; methods; and what type of subjects (human or animal), if applicable. The body should be no longer than 15-20 pages (12-point type, standard margins).
8. Progress Report (For Renewal Projects): Include preliminary data and any relevant progress.

Research from the previous chapter in combination with additional information was used to compile the grant proposal.

Chapter IV

Discussion

The aim of this dissertation was to evaluate the potential benefits of SFA systems on standardized test scores in the elementary school age population through an extensive literature review that was used to develop a grant proposal. The decision to evaluate SFA as the device of choice was selected through careful and precise literature reviews of classroom acoustics, current classroom assistive device technology, and the associated benefits of SFA. A grant proposal for funding was drafted in order to conduct future research to examine the effects of SFA on standardized tests.

Request for Proposal

The grant proposal was created to obtain four SFA systems to be placed in 3rd and 4th grade elementary classrooms at the beginning of the school year in which they are scheduled to take the Louisiana standardized test, LEAP and *i*LEAP. Those scores will then be obtained and statistical analysis to examine the effects of SFA on standardized test scores will be conducted. Furthermore, the goal of the American Research Hearing Foundation grant is to explore new technologies and ideas in the field of audiology directly related to hearing and balance. Award of the grant proposal would allow for exploration of benefits associated with the use of SFA in areas of standardized test scores.

Currently, there is a lack of empirical evidence exploring the relationship of SFA and Federal mandated high-stakes standardized tests required by the NCLB law of 2002.

The literature review clearly shows the vast benefits of SFA technology such as the ability to improve poor classroom acoustics, overall academic achievement, speech recognition, literacy, phonological awareness, reading comprehension, listening comprehension, and classroom attention and learning behaviors for students with normal hearing and those with hearing impairment. Therefore, a grant proposal was developed to secure funding for the purpose of obtaining SFA systems to examine the effects of SFA on standardized test scores.

Conclusion

Throughout the literature review it is evident that many classroom environments lack appropriate acoustical standards to ensure optimal learning conditions despite the fact that research on SFA systems has demonstrated the ability to overcome poor listening environments. This is especially crucial during the early school grades when the fundamental educational skills necessary for academic success are developed. Furthermore, the State of Louisiana conducts standardized test assessments (LEAP and *i*LEAP) to measure the students' knowledge and skills. These standardized test scores not only determine if the student progresses to the next grade, but also influences the amount of federal revenue and how the revenue is allocated to the schools. Therefore, the purpose of the grant is to purchase SFA systems to be placed in classrooms that will undergo standardized testing, ultimately comparing standardized tests scores for students in classrooms that both use and do not use SFA.

When sampling the research on State implemented standardized tests, many factors have been identified as influencing student performance on these standardized tests. For example Beckman et al. (2012) found that English as a second language and poverty were indicators of students who performed the lowest on standardized test. Likewise, Von der Embse and Hasson (2012) found a significant relationship between high anxiety levels and poor performance on high-stakes standardized test. Furthermore, Lee (2013) and Wheelan and Kesselring (2005) found that school demographics, school resources, and the ability of the school faculty members to work together as a group influenced the students' performance of standardized test.

Additionally, SFA systems have been shown to increase student academic performance, improve speech discrimination, increase attention, and improve classroom behavior for a diversity of students such as those with English as a second language, children with hearing loss, children with normal hearing, and students in schools with low socioeconomic status (Eriks-Brophy & Ayukawa, 2000; Langlan et al., 2009; Massie & Dillon , 2006). As seen in the literature review above, SFA has received overwhelmingly positive reports from teachers and students. In addition, teachers reported less vocal strain/fatigue and effort with the use of SFA. Therefore, it is suspected that the use of SFA would result in higher scores on standardized tests such as the LEAP and *i*LEAP and would aid in improving overall student academic performance, reduce teacher vocal strain, and enhance the learning environment. It is hopeful that evaluating the relationship of SFA and its effects on state mandated standardized tests will further demonstrate the value and necessity of utilizing SFA in classroom.

Appendix A

American Hearing Research Foundation General Grant Application

American Hearing Research Foundation General Grant Application

The American Hearing Research Foundation funds four to six $20,000 research grants each year. Applications are reviewed by a Research Committee and awards begin in January. Research Grants should relate to the hearing or balance functions of the ear. Both basic and clinical studies may be proposed. Priority is given to providing startup funds for new projects. To apply for a Research Grant, please adhere to the following guidelines. Applications are due no later than noon on August 15 of the previous year. Please submit an electronic copy (PDF or Word is fine) to info@american-hearing.org.

The Grant Applications should contain the following parts:

Part	Description
Delivery	Please e-mail a Word or PDF of your proposal to info@american-hearing.org. Your document file name should be labeled: Lastname_Firstname, i.e., Smith_John. Do not include "AHRF Grant application" or anything else in your file name.
Title Page	Include title of project, principal investigator(s), mailing address, phone number, and e-mail address of the individual or institution that is applying for the funding. Be sure this information is on the FIRST page of your proposal. Please indicate whether you are a PhD, MD or both. Be sure to include the name and ALL contact information (including address, phone and e-mail) of the financial officer to whom we should send a check should your proposal receive a grant.
Description	Include a brief description of the project. Also include performance site and key personnel.
Table of Contents	Include all first-level headings with page numbers.
Detailed Budget	Provide a one-year budget (or two-year budget if you are applying for a special grant that spans two years) that includes salary for support staff (students, post-doctorate fellows, etc.), equipment, and supplies. Do not include salaries for principal investigator(s), travel expenses, or overhead; the AHRF does not fund these costs. Your budget should include the total amount requested.
Biographical Sketch (One For Each Principal Investigator)	Please include your contact information (at least phone and e-mail) on the biographical sketch page. List all publications (maximum, two pages), current funding, pending funding, and requested funding. Please indicate what you will do if you receive overlapping funding. Letters of support from colleagues are welcome, but not

	required. Please include any letters of support within your proposal document whenever possible.
Main Body	Include specific aims of the project; background and significance; methods; and what type of subjects (human or animal), if applicable. The body should be no longer than 15-20 pages (12-point type, standard margins).
Progress Report (For Renewal Projects)	Include preliminary data and any relevant progress.

Appendix B

Grant Proposal

Grant Proposal

Effects of Sound Field Amplification on Standardized Test Scores

Principal Investigators:
Melinda Bryan, Ph.D., CCC-A & Jessica Ivey Coker, M.S.
Louisiana Tech University
306 Robinson Hall
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Melinda F. Bryan: melinda@latech.edu
Jessica Ivey Coker: jivey4119@yahoo.com

Applying for the AHRF Grant

Financial Officer: Louisiana Tech University
Name: Ms. Lisa Cole
Address: P.O. Box 7924
Ruston LA, 71272
Phone: 318-257-4325
Fx: 318-257-2234
Email: lcole@latech.edu

DESCRIPTION

The acoustical environment in today's classrooms poses many challenging obstacles to listening and learning for young school-aged children. Within the classroom, factors such as internal and external background noise, reverberation, speaker-to-listener distance, and poor acoustical treatments can interfere with listening and learning (Eriks-Brophy & Ayukawa, 2000). Often these variables are compounded with other issues such as a hearing impairment, learning disability, auditory processing disorder, or learning English as a second language. To combat these issues, sound field amplification (SFA) has been recommended by researchers, clinicians, and educators as a solution to overcome the acoustical learning barriers (Wilson, Marinac, Pitty, & Burrows, 2011). SFA is a system where the teacher wears a microphone and there are speakers mounted throughout the room. This system allows all the students to hear the teachers' voice regardless of the distance or location of the teacher in the classroom. Furthermore, many studies have documented the benefits of SFA for children with normal hearing, hearing impairment, and developmental delays (Langlan, Sockalingam, Caissie & Kreisman, 2009). These benefits include improvements in overall academic achievement, speech recognition, literacy, phonological awareness, reading comprehension, listening comprehension, attention, and learning behaviors (Anderson & Goldstein, 2004; Rosenberg, et al., 1999; Rubin, Flagg-Williams, Aquino-Russell, & Lushington, 2011; Wilson et al., 2011). While the benefits of SFA are prevalent for all children, the actual implementation of SFA systems in the educational system is rather scarce. Furthermore, a search of the literature revealed there is a lack of empirical studies evaluating the effects of SFA on State administered standardized test scores of elementary students. Therefore, the primary objective of this application is to receive grant funds to purchase sound field amplification (SFA) systems to be used in elementary school classroom in Ruston, Louisiana. Specifically, if awarded, this grant will be used to purchase four SFA systems, which will be placed in two 3rd grade classrooms and two 4th grade classrooms in Lincoln Parish School District (Ruston, LA). Particularly, the SFA systems will be placed in four experimental classrooms (two SFA systems at two different schools) at the beginning of the school year and will be used continually throughout one school year. Additionally, control groups will include a comparison 3rd and 4th grade classroom without the use of SFA from each school. During the month of April, Louisiana students in the 3rd and 4th grade will be assessed by state mandated standardized tests. Essentially, standardized test scores from the treatment groups and control groups will be collected and statistical analyzed to determine if students taught with the use of SFA demonstrated a significant improvement in test scores compared to those students who were taught without the use of SFA. Melinda Bryan, Ph.D., CCC-A, a treatment audiologist and professor who teaches coursework in amplification and aural rehabilitation, will serve as key personnel for this project. Her role will be the selection, purchasing, set-up, training, and monitoring of device performance as well as analysis of the results. Therefore, the grant will be used to purchase SFA systems to be used in future experiments by Louisiana Tech University for the collection of research data on the efficacy and value of using SFA devices as the recommended standard in elementary classrooms and highlight its potential effects on standardizes test scores.

TABLE OF CONTENTS

DETAILED BUDGET

***Agency:* American Hearing Research Foundation**
***Due:* August 1, 2015**
Project Title: Effects of Soundfield Amplification on Standardized Test Scores

Proposed Budget	Support Requested	Institution Match
A. Personnel		
1. Research Faculty		
Name:	$ -	$ -
2. Staff	.	
Clerical	$ -	$ -
Post Docs	$ -	$ -
3. Subtotal	$ -	$ -
4. Fr. Ben. (32.4%, 35.4%, 23.3%)	$ -	$ -
5. Graduate Assistants	$ -	$ -
6. Undergraduate Students	$ -	$ -
7. Subtotal A	$ -	$ -
B. Supportive Expenses		
1. Travel	$ -	$ -
2. Operating Services	$ -	$ -
3. Supplies	$ 500.00	$ -
4. Software	$ -	$ -
5. Equipment	$ 6,989.56*	$ -
6. Consultants	$ -	$ -
7. Other Expenses		
a. O/S Tuition Waver	$ -	$ -
b. Lab Use Fees	$ -	$ -
8. Subcontracts	$ -	$ -
9. Subtotal B	$ **7,489.56**	$ -
C. Overhead		
State: 22% of TDC	$ 1,647.70	$ -
TOTAL	**$ 9,137.26**	$ -

Total Direct Costs $ **9,137.26** $ -

*Funding if awarded will be used to purchase SFA systems including the Roger DigiMaster 5000 (825.00) with Roger Inspiro-easyboom transmitter (855.00) plus 67.39 for shipping & handling ($825 + $855 + $67.69 = $1747.39 x 4 systems = $6,989.56). Installation and set it up will be provided by Phonak.

BIOGRAPHICAL SKETCH – Melinda F. Bryan, Ph.D., CCC-A

Melinda F. Bryan, Ph.D., CCC-A
Robinson Hall, Room 214B
PO Box 3165
Ruston, LA 71272
Phone: 318-257-2146
Email: melinda@latech.edu

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
University of Central Arkansas, Conway, AR	B.S.	05/2001	Speech Pathology Minor: Mathematics
University of Tennessee, Knoxville, TN	M.A.	05/2003	Audiology Minor: Aural Rehabilitation
University of Tennessee, Knoxville, TN	Ph.D.	08/2006	Speech & Hearing Science

Publications

1. Pack, K., **Bryan, M.F.** (under review). Effects of Untrained Earmold Impression Taking on Custom Hearing Protector Device Performance. *International Journal of Audiology.*
2. Hayes, D., Eddins, D., & **Bryan, M.F**. (under review). Improvements in Speech Perception in Noise due to smartFocus™ Signal Processing. *Journal of American Academy of Audiology.*
3. **Bryan, M.F.**, Franklin, C., Ware, K.S., Horne, R. (2013). Acceptable Noise Levels in Preschool Children with Normal Hearing. *Journal of the American Academy of Audiology,* 24(9), 823-831.
4. Kim, J. & **Bryan, M.F.** (2011). The Effects of Asymmetric Directional Microphone Fittings of Acceptance of Background Noise. *International Journal of Audiology,* 50, 290-296.
5. **Freyaldenhoven, M.,** Nabelek, A., & Tampas, J. (2008). Relationship between Acceptable Noise Level and the Abbreviated Profile of Hearing Aid Benefit. *Journal of Speech, Language, and Hearing Research*, 51, 136-146.
6. **Freyaldenhoven, M.**, Plyler, P., Thelin, J., & Muenchen, R. (2008). Acceptance of Noise Growth Patterns in Hearing Aid Users. *Journal of Speech, Language, and Hearing Research*, 51, 126-135.
7. **Freyaldenhoven, M.**, Plyler, P., Thelin, J., & Hedrick, M. (2007). The Effects of Speech Presentation Level on Acceptance of Noise in Listeners with Normal and Impaired Hearing. *Journal of Speech, Language, and Hearing Research*, 50, 878-885.
8. Nabelek, A., Tampas, J., & **Freyaldenhoven, M.** (2007). Further Questions about the Acceptable Noise Level Test: A Response to Dr. Hamill. *Journal of the American Academy of Audiology*, 18(2), 185-187.

9. **Freyaldenhoven, M.** & Smiley, D.F. (2006). Acceptance of Background Noise in Children with Normal Hearing. *Journal of Educational Audiology*, 13, 27-31.
10. Nabelek, A., **Freyaldenhoven, M.**, Tampas, J., Burchfield, S., & Muenchen, R. (2006). Acceptable Noise Level as a Predictor of Hearing Aid Use. *Journal of the American Academy of Audiology,* 17(9), 626-639.
11. **Freyaldenhoven, M.**, Smiley, D.F., Muenchen, R., & Konrad, T. (2006). Acceptable Noise Level: Reliability Measures and Comparison to Background Noise Preference. *Journal of the American Academy of Audiology*, 17(9), 640-648.
12. **Freyaldenhoven, M.**, Plyler, P., Thelin, J., & Burchfield, S. (2006). Acceptance of Noise with Monaural and Binaural Hearing Aid Use. *Journal of the American Academy of Audiology*, 17(9), 659-666.
13. **Freyaldenhoven, M.**, Plyler, P., Thelin, J., Nabelek, A., & Burchfield, S. (2006). The Effects of Venting and Low Frequency Gain Compensation on Performance in Noise with Directional Hearing Instruments. *Journal of the American Academy of Audiology,* 17(3), 168-178.
14. **Freyaldenhoven, M.**, Thelin, J., Plyler, P., Nabelek, A., & Burchfield, S. (2005). Effect of Stimulant Medication on the Acceptance of Background Noise in Individuals with Attention Deficit/Hyperactivity Disorder. *Journal of the American Academy of Audiology*, 16(9), 677-686.
15. **Freyaldenhoven, M.**, Nabelek, A., Burchfield, S., & Thelin, J. (2005). Acceptable Noise Level (ANL) as a Measure of Directional Benefit. Journal of the American Academy of Audiology, 16(4), 228-236.

Selected Presentations (last 5 years):

1. **Bryan, M.F.** (April, 2014). *Soundfield Amplification in Temporary Classrooms and Performance Characteristics of RITE Hearing Aids.* Louisiana Board of Examiners for Speech Pathology and Audiology Annual Conference (Baton Rouge, LA).
2. Alanazi, A., Atcherson, S., Franklin, C., **Bryan, M.F.** (April, 2014). *Acoustics of Conventional & Amplified Stehoscopes for Health Professional with Hearing Loss.* Poster Presentation at 2014 Audiology Now Convention (Orlando, FL).
3. Pack, K., **Bryan, M.F.** (March, 2014). *Effects of Untrained Earmold Impression Taking on Custom Hearing Protector Device Performance.* Oral Presentation at the 2014 National Hearing Conservation Association Convention (Las Vegas, NV).
4. Babin, S., **Bryan, M.F.,** Bryan, M.D., Shoemaker, S. (February, 2014). *A Comparison of the Effects of Soundfield Amplification on Acoustical Characteristics and Word Recognition Performance in Relocatable and Permanent Classrooms.* Poster Presentation at the 2014 LaTech Student Research Symposium (Ruston, LA).
5. Ford, A., **Bryan, M.F.,** Bryan, M.D., Shoemaker, S., Stender, T. (April, 2013). *Receiver Position and Acceptance of Noise, Speech Understanding, and Sound Quality Ratings.* Poster Presentation at Audiology Now 2013 (Los Angeles, CA).
6. Ford, A., **Bryan, M.F.,** Bryan, M.D., Shoemaker, S., Stender, T. (February, 2013). *Receiver Position and Acceptance of Noise, Speech Understanding, and Sound Quality Ratings.* Poster Presentations at the Louisiana Tech Undergraduate/Graduate Research Symposium (Ruston, LA).
7. **Bryan, M.F.** & Newman, J.L. (March, 2012). *An Acceptable Noise Level Update 2012.* Invited written presentation for Audiology Online.

8. Anderson, K.A., Bryan, M.F., Bryan, M.D., & Madix, S.M. (June, 2011). *Bluetooth Headset Specifications and its Possible Cause of Hearing Loss.* Poster Presentation at the Louisiana Speech and Hearing Association Convention (Shreveport, LA).
9. Manning, J., **Bryan, M.F.,** Bryan, M.D., & Madix, S.M. (April, 2011). *Effect of Cardiovascular Exercise on the Selection of Preferred Listening Levels using iPods.* Poster Presentation at the Louisiana Tech University Research Symposium (Ruston, LA).
10. Boynton, A., **Bryan, M.F.,** Bryan, M.D., & Madix, S.M. (April, 2011). *The Effects of Hearing Aid Circuitry and Speech Presentation Level on ANL.* Poster Presentation at Audiology Now! (Chicago, IL).
11. Eddins, D., **Bryan, M.F.,** & Hayes, D. (November, 2010). *Improving Speech Perception in Noise using SmartFocus Signal Processing.* Oral Presentation at the American Speech, Language, Hearing Association Convention (Philadelphia, PA).
12. McCann, A., Madix, S.M., **Bryan, M.F.,** & Bryan, M.D. (September, 2010). *Development of an Elementary School Background Noise.* Poster Presentation at the Louisiana Tech University Research Symposium (Ruston, LA).
13. **Bryan M.F.,** Manning, J., & Hayes, D. (June, 2010). *Impact of SmartFocus on Speech in Noise and Sound Quality Ratings.* Poster Presentation at the Louisiana Speech and Hearing Association Convention (Baton Rouge, LA).
14. Boynton, A. & **Bryan, M.F.** (June, 2010). *Effects of Hearing Aid Circuitry and Speech Presentation Level on Acceptance of Background Noise.* Poster Presentation at the Louisiana Speech and Hearing Association Convention (Baton Rouge, LA).
15. **Bryan M.F.,** Manning, J., & Hayes, D. (April, 2010). *Impact of SmartFocus on Speech in Noise and Sound Quality Ratings.* Poster Presentation at Audiology Now! (San Diego, CA).

Current Funding:

German Pellets GmbH. (2014). "Bird Communities of Lincoln Parish Park and Effects of Timber Harvest and Hearing Amplification on Birds and Bird Detections." Principal Investigators: James Dickson & **Melinda F. Bryan**. $5,000 awarded over 3 years.

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Publications
None

Presentations

1. Newman, J., **Coker, J. I.,** Latininen, K. (October, 2013). *Hearing Conservation and Safety Awareness.* Presentation for Louisiana Tech Department of Music. (Ruston, LA).
2. **Coker, J. I.** (October, 2014). *Progressive Tinnitus Management.* Invited lecturer for graduate audiology course at Louisiana Tech University. (Ruston, LA).

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MAIN BODY

Specific Aims of the Study

In order for students to learn in the classroom, they must be able to hear and focus on what the teacher is saying. To this end, the American National Standards Institute (ANSI) has developed standards for classroom acoustics that are designed to achieve optimal speech intelligibility for students (ANSI, 2010). Unfortunately, the majority of classrooms fail to meet these standards and many children continue to experience academic difficulties due to poor classroom acoustics (Rosenberg et al., 1999).

To help overcome the acoustical learning barriers, sound field amplification (SFA) devices have been recommended by researchers, clinicians, and educators (Wilson et al., 2011). SFA systems amplify the teachers' voice through loudspeakers, which are placed around the classroom. Therefore, all students are able to hear the teachers' voice regardless of the location of the teacher in the classroom. The benefit of SFA for children with normal hearing, hearing impairment, and developmental delays has been well documented (Langlan et al. 2009). These benefits include improved overall academic achievement, speech recognition, literacy, phonological awareness, reading/listening comprehension, and attention (Anderson & Goldstein, 2004; Rosenberg, et al., 1999; Rubin et al., 2011; Wilson et al., 2011). While the benefits of SFA are surmounting for all children, the actual implementation of SFA systems in the educational system is rather scarce.

A search of current literature revealed that no study has yet to address the effects of SFA on standardized test scores. According to the US Department of Education (USDE, 2002), the federal No Child Left Behind (NCLB) Act of 2001 requires every State to administer an annual test in the core subjects of English, Language Arts, and Mathematics in grades three through eight and at least once in grades 10 through 12. Schools must be in compliance with this law in order to maintain federal and state funding (USDE, 2002).

Therefore, the aim of the proposed research is to investigate the effects of SFA on the Louisiana Educational Assessment Program (LEAP) standardized test. In accordance with NCLB Act, the LEAP test is a series of tests that fourth and eighth grade students take each year to determine if they need summer school remediation or to be retained. The LEAP scores are used as a direct representation of the school districts' and students' proficiency achievement level.

In summary, many classroom environments lack appropriate acoustical standards to ensure optimal learning conditions. During the early school grades, it is especially crucial that students overcome poor listening environments to obtain the fundamental educational skills necessary for academic success. Furthermore, the State of Louisiana conducts standardized test assessments (LEAP) to measure the students' knowledge and skills gained during that grade. These standardized test scores not only determine if the student progresses to the next grade but also influences the amount of federal revenue and how the revenue is allocated to the schools. A proposed remedy to reduce poor acoustics is through the use of SFA. To this end, if funded, a grant award will be used to obtain SFA systems to be placed in public elementary schools for the purposes of furthering data collection on this topic.

Furthermore, a grant award will allow for the collection of experimental data that will investigate the effects of SFA on standardized test as well as support the results of SFA research reported in the literature. Furthermore, it is expected that test scores with the use of SFA will demonstrate the necessity and underestimated value of providing an audible teaching signal in inherently noisy classrooms of elementary school-aged population.

Background and Significance

Classroom Acoustics

The predominant teaching method used in mainstream classrooms is auditory verbal (i.e., the teacher lectures to the class); however, the acoustical environment in today's classrooms poses many challenges to listening and learning. Specifically, within the classroom, factors such as internal and external background noise, reverberation, speaker-to-listener distance, and poor acoustical treatments can interfere with listening and learning (Eriks-Brophy & Ayukawa, 2000). Often these variables are compounded with other issues such as a hearing impairment, learning disability, auditory processing disorder, and/or learning English as a second language.

Recommended acoustical standards. It has well been established that the better a child can hear, the more they can understand and learn (Anderson & Goldstein, 2004; Wilson et al., 2011). Furthermore, extensive research has shown that unfavorable acoustic conditions in the classroom diminish speech audibility and intelligibility, have detrimental effects on a student's psychoeducational and psychosocial achievement, and pose negative effects on teacher's energy levels and vocal health (Berg, Blair, & Benson, 1996; Klatte & Hellbruck, 2010). In an effort to rectify unfavorable listening environments and promote successful learning environments, the Acoustical Society of America and the American National Standards Institute (ANSI) developed the ANSI S12.60 standard (ANSI, 2010). The ANSI (2010) recommendations state that (1) permanent, unoccupied classroom levels should not exceed 35 dBA; (2) the signal-to-noise (SNR) should be +15 dB (i.e., the signal should be presented 15 dB above the noise in the classroom); and (3) unoccupied classroom reverberation time (RT) must not surpass 0.7 seconds. The published standards by ASHA are similar to the ANSI standards with the exception that ASHA (2005) recommends that RT should not exceed 0.4 seconds. Currently, compliance with the ANSI and ASHA standards is voluntary; however, many school districts and state and local agencies are beginning to incorporate these standards into their construction or renovation efforts to improve classroom/school acoustics. With that said, the majority of classrooms fail to meet these standards (ASHA, 2005). As stated previously, both ANSI and ASHA address three main acoustical parameters that interfere with the quality of the classroom listening and learning environment: background noise, signal-to-noise ratio (SNR), and reverberation time (RT). The implications of these three acoustical variables on classroom acoustics will be further discussed below.

Background Noise. One acoustical parameter that affects a child's ability to learn in the classroom is background noise. In a review article by Crandell and Smaldino (2000, p. 363), background noise is define as, "any undesired auditory stimuli that interferes with what a child wants or needs to hear." In essence, background noise is extraneous sound(s) that mask the signal of interest. It can be categorized as external noise, internal noise, and classroom noise. External noise is comprised of sounds from outside the building, such as playgrounds, automobile traffic, local construction, or outside air-conditioning units. Internal noise arises from within the building but outside the classroom, such as adjacent rooms, gymnasiums, and busy hallways (Tye-Murrary, 2009). Room noise originates from inside the classroom and includes shuffling papers, moving chairs or tables, children talking, and heating, ventilating, and air-conditioning (HVAC) systems. Furthermore, research has continually demonstrated that the typical classroom background noise levels range from 39.8 to 70 dBA, which is substantially higher than the ANSI and ASHA recommendations of 35 dBA (Crandell & Smaldino, 2000; Eriks-Brophy & Ayukawa, 2000; Nelson, Kohnert, Sabur, & Shaw 2005; Knecht, Nelson, Whitelaw & Feth, 2002).

In a study of acoustics conducted by Rubin et al. (2011), they analyzed various aspects of classroom listening environments in eight schools across three Canadian school districts, with the purpose of making recommendations for improving listening and learning. Measurements of the classroom noise levels were made with and without SFA, and teachers and student opinions regarding SFA were obtained. Results of mean background noise levels were reported from 33.6 to 52.3 dBA in two schools, School X and School Y. All 14 classrooms in School X failed to meet the ANSI standard for classroom acoustics. Results further showed that 85% of the students would respond more when the teacher addressed them in the amplified condition (i.e., with SFA). When the teacher addressed the class, there was a significant decrease in distractive communicative interactions among students for the amplified classroom. Lastly, interviews with teachers and students reported overall ratings of the SFA were generally positive (87%) with only a few problems noted, such as issues with feedback and setting the volume too high. Based on the findings from Rubin et al. (2011), only 31% of the classrooms tested met ANSI recommended standards, suggesting that classrooms with poor acoustics demanded more energy for students to focus and concentrate. Furthermore, the researchers concluded that the use of SFA reduced distractive communicative behaviors and improved the students' ability to focus. This study recommended school personnel to be conscious of the important factors of creating optimal classroom listening environments through knowing the student's characteristics, room acoustics, and the effectiveness of SFA.

Signal-to-noise ratio (SNR). A second crucial variable to consider within the classroom environment is the SNR. SNR is the difference in decibels between the intensity level of the speech signal compared to the intensity level of the noise. The SNR relationship is favorable when the signal is higher than the background noise. Conversely under increased background noise, the SNR decreases resulting in poor listening environments. As previously stated, ANSI (2010) and ASHA (2005) standards recommend at least a +15 dBA SNR for adequate speech perception to occur in the classroom; however, the typical SNR surpasses this limit. For instance, research examining SNRs in typical unoccupied classrooms have been reported to range from +5 dB to -7 dB and in an occupied classroom to range from +3.0 to -17.6 dB (Crandell & Smaldino's 2000; Larsen & Blair 2008; Rubin et al., 2011), thus, indicating excessive noise levels in most learning environments. Similar studies have demonstrated the benefits related to improving the SNR with the use of SFA in the classroom. For example, Larsen and Blair (2008) recorded SNRs from the teacher's speech ranging from +11 to +15 dB with the use of SFA. Furthermore, Eriks-Brophy and Ayukawa (2000) demonstrated the benefits of improving the SNR with the use of SFA for students with hearing loss, behavioral difficulties, normal hearing, attention or behavioral difficulties, as well as second language learners.

Reverberation time (RT). The third influential acoustical variable that can have devastating effects on listening and learning in the classroom is reverberation. Reverberation is the prolongation of sound after the signal has stopped. Specifically, the RT in a room refers to the amount of time, in seconds, it takes for the sound to diminish by 60 dB once the source of the sound has ended (Berg et al., 1996; Crandell & Smaldino, 2000; Dockrell & Shield, 2012). The problem with long RT is that it has a negative impact on speech intelligibility. This is because the speech reflects s back to the listener and overlaps fragments of the original signal, which causes masking or "smearing" of the speech signal (Knecht et al., 2002). Research evaluating average classroom RT has documented that these measurements commonly exceed the recommend ASHA (2005) and ANSI (2010) standards (Crandell & Smaldino, 2000; Knecht et al., 2002; Wilson et al., 2011). Furthermore, research by Klatte and Hellbruck (2010) has demonstrated that poor classroom acoustics, such as an increase in ambient noise due to the high RT, leads to students' perception of more annoyance by the noise, subsequently reflecting poorer reading abilities and school attitudes. In summary, unfavorable classroom acoustics such as long RTs, poor SNR, and increased background noise have all been shown to significantly impede a child's ability to listen and learn in a classroom. Research continually shows how poor classroom acoustics negatively impacts not only children with normal hearing but those with hearing loss and other learning disorders. Through improving poor acoustical parameters, research has numerously demonstrated the positive effects such as improved listening ability, increased academic performance, and better classroom behavior.

Assistive Listening Devices

The use of listening devices has been proven beneficial and cost-effective in reducing the negative effects associated with poor classroom acoustics (Boswell, 2006). There are several different types of assistive listening devices such as personal frequency modulated (FM) systems, infrared systems, induction loop systems, and SFA systems that have been used to help students hear the teacher and overcome adverse listening conditions (ASHA, 2002; Kreisman, 2002). Generally, each system has a microphone that is used by the speaker/teacher. The input signal (i.e., teacher's voice) is then amplified and sent to a receiver, which is used to transmit a louder signal to the listener/student (Tye-Murrary, 2009).

Sound field Amplification (SFA) Systems. As stated previously, one type of assistive listening device is a SFA system. This system consists of a microphone (worn by the teacher), amplifier, and loudspeakers, which are placed strategically around the classroom. Generally, there are between two or four loudspeakers in the classroom (Tye-Murrary, 2009). This technology allows all the students to hear the teachers' voice regardless of the distance or location of the teacher in the classroom (Berg et al., 1996; Dockrell & Shield, 2012). Furthermore, SFA systems aim to provide a SNR of approximately +10 to 15 dB throughout the classroom. For that reason many researchers and clinicians have supported the use of SFA systems in classrooms for children with hearing impairment, normal hearing, and those at risk of other learning and developmental disabilities (Berg et al., 1994; Anderson & Goldstein, 2004; Dockrell & Shield, 2012).

Several advantages of SFA system have been identified in the research. The biggest benefit is the overall improved signal for everyone in the classroom regardless of hearing status. This is especially beneficial due to the high incidence of fluctuating middle ear infections in younger school-aged children. Furthermore, since children in the classroom do not have to wear any extra equipment (i.e., the speakers are mounted throughout the classroom), the social and emotional stigmatization associated with wearing a device to hear better is reduced. There is also no further cooperation needed from the students to receive the amplification.

SFA systems are relatively easy to use and require little to no maintenance or troubleshooting for the teacher/school personnel. SFA systems are also viewed as cost effective since all students can benefit with the cost of purchasing one SFA unit for each classroom. One of the disadvantages includes lack of portability. For instance, each classroom must have its own system installed. Another limitation concerns the placement of the loudspeakers. Due to a variety of classroom sizes, shapes and arrangements, the loudspeakers must be installed optimally to avoid introducing distortion. Lastly, SFA alone does not provide sufficient amplification for those with more than a mild degree of hearing loss (Lewis, 1994).

Benefits of SFA. There are a plethora of studies that evaluate the various impacts offered by SFA, such as enhancing classroom acoustics, amplifying the teachers' voice to reduce vocal strain, improving student behavior and attitudes, and increased academic performance. The following section will examine studies that provide supporting evidence for the use of SFA in classrooms.

The primary way that SFA has the ability to minimize the negative effects of poor classroom acoustics is through the enhancement of the SNR. This was demonstrated by Larsen and Blair (2008), who evaluated the SNR of 4th grade classrooms while class was in session and students were interacting with the teacher and peers. When SFA systems were placed in five classrooms that met ANSI classroom guidelines, the amplified SNR from the teacher's speech ranged from +11 to +15 dB, while the unamplified SNR results were significantly lower (+1 to +6 dB). Also, student comments showed that without the use of SFA, students may miss what other students are saying during classroom discussions or when reading aloud. Therefore, this study provided evidence that even when the classroom acoustics are favorable, SFA has the ability to both increase the SNR in the classroom and improve student's ability to hear other students (Larsen & Blair, 2008).

Eriks-Brophy and Ayukawa (2000) demonstrated similar results through the investigation of a study aimed to document the usefulness of SFA by investigating student performance on speech intelligibility measurers, attending behaviors, and, teacher and student statements concerning SFA. The results revealed that both students with and without hearing loss had significant improvements (at least 10%) in speech intelligibility scores when the SFA system was in use. Furthermore, attending behaviors improved when SFA was used, and the overall ratings of the SFA systems were positive and well accepted in the classroom by the teachers and the students. These results show that SFA systems are valuable in classrooms.

Additionally, Dockrell and Shield (2012) examined the impact of SFA on teaching and learning in elementary classrooms. The study showed that the use of SFAs improved listening and attending to verbal instruction as measured by teacher ratings and student performance. Furthermore, the study showed that classroom amplification significantly improved the student's listening comprehension. Notably, the results showed that classrooms with poorer acoustics (longer RTs) showed greater improvement in listening comprehension with SFAs in contrast to the students in rooms with better acoustics (shorter RTs). From the results, the authors concluded that SFA improved performance of listening comprehension and classrooms with poorer acoustics benefited the most.

Similarly, an extensive three year study called the Improving Classroom Acoustics project (ICA) was carried out in two phases by Rosenberg et al. (1999) to investigate if the use of SFA improved elementary student's listening and learning behaviors. Results of Phase I of the study found that students in classrooms with SFA demonstrated significantly greater improvements in listening and learning behaviors compared to students without classroom amplification. Phase II included SFA in all classrooms and consisted of pre- and post-amplification observations of the classrooms. Phase II results also indicated significant improvements for the students, as rated by the teachers, with SFA. Furthermore, students, parents, and administrators provided overall positive evaluation of SFA. In summary, Rosenberg et al. (1999) demonstrated that significant improvements in listening and learning behaviors could be achieved with the use of SFA. Furthermore, they showed that this improvement progressed at an increased rate when compared to grade matched peers in unamplified classrooms. They found that the greatest improvement occurred with the younger students in an amplified classroom, thus providing additional support for the use and the benefits for SFA. Therefore, Rosenberg et al. (1999) supports the use of SFA to enhance the listening and learning conditions of the classroom.

Langlan et al. (2009) also aimed to investigate if the use of SFA had a direct effect on the student's classroom performance. They examined students with and without hearing loss. Results from the study demonstrated that all of the students showed significant improvements in the areas of academics, attention, communication, class participation, and school behavior with the use of the SFA system. However, once amplification was discontinued, student performance was not sustained, indicating that the improvements only occurred during the actual use SFA. Furthermore, students with hearing loss, as well as those possibly suffering from fluctuating otitis media (i.e., ear infection), were shown to greatly benefit from the use of SFA. In addition, results from the teachers' survey showed less vocal strain and a general feeling that their students understood them better and were consistent with other findings of teacher satisfaction with SFA. In summary, these results further provide evidence of the efficacy of SFA to improve classroom performance for elementary students with normal hearing acuity and those with hearing loss.

Furthermore, Darai (2000) conducted a study over five months to investigate the impact of SFA on literacy scores of first-grade students. Because hearing plays a significant role in a child ability to learn to read, the purpose of this research was to examine the connection between classroom amplification and literacy outcomes. Results on the literacy assessment showed greater literacy gains for the four experimental classrooms with SFA compared to the four control classrooms without SFA. Teachers reported that the improved acoustics with SFA also helped to facilitated language and phonics instruction as well reduce teacher vocal strain. The teachers also reported that the students were more attentive, and all teachers in the experimental classrooms rated the SFA as "highly beneficial." Based on these results, Darai (2000) concluded that first-grade students in amplified classrooms were able to achieve significantly higher gains in literacy compared to those in the control group without SFA. This research highlights the importance of using SFA as a method of improving classroom acoustics, improving the teacher's vocal strain, and enhancing the listening and leaning environment for better literacy achievement.

Similarly, Purcell and Millett (2010) examined the effects of SFA on reading outcomes for first grade students who were in classrooms with SFA compared to students who were in classrooms without amplification. The results indicated a greater percentage of students reading at grade level in the amplified classroom than the unamplified classroom. Additionally, the teacher assessments indicated that their experience with SFA was "extremely positive," and 100% of the teachers reported less vocal strain. Based on these results, Purcell and Millett (2010) concluded that an increase in the percentage of first grade students reading at grade level at the end of the year with SFA verses the unamplified classrooms. Also, students identified as "at-risk" and receiving early reading intervention showed greater improvements in the amplified classrooms when compared to the unamplified classrooms. Thus, the use of SFA in classrooms is shown to provide positive benefits for improving literacy outcomes for typical students and those at risk for reading problems.

Lastly, Massie and Dillon (2006) examined the effects of SFA on attainment of reading, writing and, numeracy skills for children in second grade. The educational outcomes were evaluated using a second grade diagnostic education monitoring system, which is a method of early monitoring and assesses student's development in literacy and numeracy. The results for the educational outcomes showed a significant improvement for SFA system 'ON' when comparing the SFA 'OFF' condition. The results showed greater improvements in all three skills (i.e., reading, writing, and numeracy skills) in the amplified condition. Based on these results, Massie and Dillon (2006) found that the effects of SFA were beneficial for the three skill areas of reading, writing, and numeracy. These beneficial effects were seen for both students with English as a native language and those with English as a second language. These results provide support for the use of SFA enhancing the attainment of literacy and numeracy skills in elementary school.

In summary the evidence supporting the use of SFA in classrooms is surmounting. As seen through the above research, SFA has been shown to improve classroom acoustics resulting in a better SNR, enhancing the learning environment, increasing the ability for listening and learning, increasing speech intelligibility, and improving teacher vocal strain. The use SFA has also demonstrated beneficial effects in areas of academics such as pre-literacy skills, literacy, writing, numeracy, and listening comprehension. Also SFA has shown positive effects on overall classroom behaviors, attention, on-task behaviors, and classroom participation. SFA has beneficial effects for a wide range of students including those with English as a second language, diverse racial and ethnic backgrounds, normal hearing, hearing impaired, students at risk for learning challenges, and younger preschool aged children. Research also reported overall ratings of the SFA systems were positive and well accepted in the classroom by teachers and students.

Standardized Testing

The benefits of SFA has been well studied and documented as noted above in areas of overall academic achievement, speech recognition, literacy, phonological awareness, reading comprehension, listening comprehension, attention and learning behaviors. However, a question concerning SFA that has not received adequate attention is whether the use of SFA will improve standardized test scores. A search of the available literature has resulted in no studies investigating the effects of SFA on standardized test scores. According to the U.S. Department of Education (USDE, 2002), the federal NCLB aims to improve the performance of primary and secondary schools by increasing the standards of accountability at the school, district, and state level. To achieve this goal, NCLB aims to utilize nationwide mandated achievement standards as measured by standardized achievement test scores and associated accountability measures. NCLB requires every state to administer annual tests (i.e., standardized tests) in the core subjects of English Language Arts (ELA), mathematics, and science and social studies in Grades 3 through 8 and at least once in Grades 10 through 12. In an effort to make schools more accountable, NCLB requires that the schools meet or show adequate yearly progress (AYP) towards standards of proficiency. Schools must also be in compliance with this law in order to maintain federal and state funding. If progress is not being made, the school may face heavy consequences such as federal sanctions, loss of federal funds, and possible school restructuring (NCLB, 2001). Due to the NCLB, standardized testing has become an essential learning assessment tool and indicator of student and school success.

The NCLB law requires that states set their own challenging academic content and performance standards. Thus, the State develops its own test or adopts a test to be given to the students for the purpose of measuring student achievement and then holds the school accountable for improving academic achievement. Furthermore, the states set their own proficiency standards that students must meet on the standardized test. In accordance with the accountability requirements of NCLB, states must ensure that all children are progressing towards the 100% proficiency goal or AYP that the state sets for itself in reading/language arts and mathematics. If the school meets the AYP goals in proficiency, then the NCLB law allows for certain rewards to be given to the schools; however, if the students' performance is lacking then rigorous accountability sanctions may be enforced.

The NCLB legislation has created a standards-based accountability system in education, through which high-stakes testing is used as a primary form of measuring school effectiveness and student achievement. The following studies explore the current literature surrounding standardized testing, accountability, and student achievement. First, Von der Embse and Hasson (2012) examined if test anxiety influenced performance scores on state administered test of high school students in urban and suburban school settings. They found no significant reaction between test performance and school setting. The results showed that students who scored lower on the standardized tests had higher anxiety scores. Based on these results, Von der Embse and Hasson (2012) concluded that the results showed a strong, negative relationship between test anxiety and the achievement scores (i.e., as test anxiety increases, test performance decreases). This study identifies test anxiety as a factor influencing high-stakes test achievement scores and the need for appropriate intervention and prevention of test anxiety.

Additionally, Beckman, Messersmith, Shepard, and Cates (2012) investigated the role that ethnicity, poverty, and language pose for 3rd, 4th, and 5th grade performance on the Nebraska State Accountability Reading Test. Furthermore, 56.5% of the student population was classified as Limited English Proficiency as defined in NCLB federal guidelines. From the results, Beckman et al. (2012) concluded that ethnicity alone was not a predictor of student performance on the Nebraska State Accountability Reading Test assessment. Their findings indicated that factors such as poverty in combination with limited English proficiency were valid indicators of student who would score lower on standardized tests. These results suggest that a combination of school poverty and limited English proficiency can negatively impact standardized high-stakes test scores. Thus, students of diverse backgrounds should be considered when accountability decisions, such as intervention resources or programs, are being made from the results of the standardized test.

Likewise, Lee (2006) investigated the effects of school accountability polices such as the input-guarantee and performance-guarantee approaches on academic achievement of fourth and eighth-grade students by evaluating standardized test results in reading and mathematics. The input guarantee approach ensures the state provides adequate key school resources such as per-pupil spending, class size, and teacher training to improve learning opportunities. In contrast, the performance-guarantee approach relies on outcomes for academic improvement through the use of high-stakes testing. The results found no relationship between the state test-driving accountability (performance guarantee) and state support for school resources (input guarantee). Next, the effects of the accountability policies and school resources on achievement were examined. Survey data from the National Assessment of Educational Progress showed improved achievement scores in mathematics for states classified as strong accountability versus those in the weak accountability states. The states' average reading and math achievement was significantly negatively associated with state pressure for school accountably and positively associated with school resources. When examining the growth rate of the average reading and math achievement scores, the gain positively related to the states' accountability policies and to the school resources. Lastly, when looking at the interaction between state accountability and support, significantly stronger math achievement gains were seen in states that demonstrated more support for school resources. Based on these results, Lee (2006) concluded that the results revealed a positive relationship between student achievement outcomes and key school resources. When performance-guarantee approach is combined with an input-guarantee approach, the results indicated that greater improvements in academics can be made. Thus, these findings indicate a relationship between school resources and student performance outcomes on standardized tests.

Furthermore, Wheelan and Kesselring (2005) examined the relationship between performance of fourth-grade students on standardized tests and the perceived effectiveness of elementary school faculty groups. They investigated the joint effects of student's performance on standardized test and the faculty's perceptions of their group working level against school demographics, including faculty size, rural or urban location, and district poverty level. The results indicated when the teachers perceived the faculty-members as a group to be functioning higher versus lower, the student performance improved on standardized tests, regardless of staff size, rural or urban location, and poverty level. Their findings suggest that even when school demographic profiles are similar, the perceived effectiveness of the faculty group could positively influence students' learning and test assessment performance; therefore, more efforts should be developed to focus on improving how the faculty group works together.

In summary, the above studies examined factors that influence outcomes on standardized test such as test anxiety, ethnicity, language, poverty, school faculty, and school polices and resources. Generally, they showed a strong, negative relationship between test anxiety and the achievement scores. (i.e., as test anxiety increases, test performance decrease and vice versa; Von der Embse & Hasson, 2012). Furthermore factors such as poverty in combination with limited English proficiency were valid indicators of students who would score lower on standardized tests (Beckman et al., 2012). Likewise, Lee (2006) showed a positive relationship between student achievement outcomes on reading and math standardized test scores and key school resources, and Wheelan and Kesselring (2005) showed that when teachers perceived faculty members to be functioning as a group, the student performance improved on standardized test, regardless of school demographics, staff size, rural or urban location, and/or poverty level. With the legislation of the NCLB (NCLB, 2001), high-stakes standardized tests have become the prominent method of evaluating student achievement and school effectiveness. Literature shows that the factors affecting standardized tests are being examined more to improve student learning and test outcomes; however, to date there are no such studies that examine the relationship of SFA and high-stakes state mandated standardized test scores.

iLEAP/LEAP Assessments. The Louisiana Educational Assessment Program (LEAP) test is a series of standardized tests that 4th and 8th grade students take each year in the state of Louisiana. This high-stakes test is based on Louisiana's Grade-Level Expectation, which measures the students' knowledge and skills in English Language Arts, Mathematics, and Science and Social Studies. The Louisiana Department of Education (LDOE) states, "students must score *basic* or above in either English Language Arts or Math and *approaching basic* or above in one other subject." If students do not score at this level, they either must complete summer school remediation or be retained to the same grade the following academic year. Furthermore, the *i*LEAP or "integrated" LEAP is a standardized test administered in 3rd, 5th, 6th, and 7th grade in Louisiana. These tests are congruent with Louisiana's content standards, benchmarks, and Grade Level Expectations in areas of English Language Arts, Mathematics, Science, and Social Studies. The *i*LEAP measures student's progress by comparing norm-referenced tests and criterion-referenced tests in order to evaluate the performance of the students' results to a national sample and the state's achievement levels. According to the LDOE, the *i*LEAP is not considered at high stakes promotional test like the LEAP; however, it is graded similarly to the LEAP test with achievement levels of *Advanced, Master (Proficient), Basic, Approaching Basic, and Unsatisfactory.*

The LEAP and *i*LEAP tests were developed in accordance with the federal NCLB education act (LDOE, 2011). The LEAP and *i*LEAP scores are used as a direct representation of the school districts' and student's proficiency achievement level (i.e., schools are graded and ranked by how well the students perform on these test each year).

Failure to show adequate yearly progress towards the statewide goals results in corrective action and restructuring measures aimed to help the school acquire State standards. Schools that meet or exceed these goals or show improvements in achievement are eligible for State Academic Achievement Awards as well as more flexibility in using Federal Education funds (U.S. Department of Education, 2002).

Rationale for the Current Study

Through much empirical evidence as reviewed above, SFA has been shown to have positive effects such as improved classroom acoustics, better listening, improved academic performance, improved student behavior, better attention, and decreased teacher's vocal strain. While there are numerous studies of the positive benefits of SFA, there is currently a lack of research investigating the effects of SFA on state mandated standardized test. Since the enactment of the NCLB legislation, state mandated standardized tests have become the primary method of measuring student achievement and school effectiveness. Therefore, performance scores on these standardized tests pose an enormous impact on both the students and the schools. For instance, the high-stakes standardized test scores determine if the student progress to the next grade or if remediation is necessary. Moreover, NCLB requires that the schools standardized test scores meet or show adequate yearly progress (AYP) towards standards of proficiency (i.e., accountability goals). Thus, standardized test scores influence the provisions of governmental funds or governmental sanctions/penalties.

If awarded, the grant proposal funds will be used to purchase SFA systems for two 3rd and 4th grade classrooms in Louisiana, and examine the effects of SFA on standardized test scores. It is hypothesized that the use of SFA will result in higher scores on the LEAP (4th grade test) and *i*LEAP (3rd grade test), and not only aid in improving overall student academic performance, but demonstrates the value and necessity of utilizing SFA in classrooms.

Methods and Procedures

If awarded, the proposed grant will be used to purchase four SFA systems that will be installed in elementary school classrooms to investigate the relationship of SFA and student performance on standardized tests (i.e., iLEAP and LEAP test scores). The proposed study will include participants from two local schools in Lincoln Parish School District in Ruston, Louisiana. Particularly, the SFA systems will be placed in four experimental classrooms (two SFA systems at two different schools) at the beginning of the school year and will be used throughout the school year. Specifically, at two different schools, SFA will be installed in a 3rd and 4th grade classroom (treatment group). Please note that teachers from the treatment classrooms will receive a SFA in-service training conducted by an audiologist. This training will provide instruction regarding the use, operation, maintenance, and troubleshooting of the SFA system. Additionally, the control groups will include a comparison 3rd and 4th grade classroom without the use of SFA from each school.

During the month of April, Louisiana students in the 3rd grade will be assessed using the iLEAP, and 4th grade students will take the high-stakes LEAP tests as mandated by NCLB Act. Essentially, test scores from the iLEAP (3rd grade) and LEAP (4th grade) tests from the treatment groups and control groups will be collected and statistical analyzed to determine if students taught with the use of SFA prior to standardized testing demonstrated a significant improvement in test scores compared to those students who were taught without the use of SFA.

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