Guidelines for Addressing Acoustics in Educational Settings

This guidelines document is an official statement of the American Speech-Language-Hearing Association (ASHA). The ASHA Scope of Practice states that the practice of audiology includes providing classroom acoustics, personal and sound field amplification, audiologic (re)habilitation, and consultation services for individuals with hearing loss and/or other auditory disorders. The Preferred Practice Patterns are statements that define universally applicable characteristics of practice. The guidelines within this document fulfill a need for more specific procedures and protocols for serving individuals with hearing loss and/or other auditory disorders in educational settings. It is required that audiologists who practice independently in this area hold the ASHA Certificate of Clinical Competence. Audiologists must also abide by the ASHA Code of Ethics, including Principle of Ethics II Rule B, which states: "Individuals shall engage in only those aspects of the profession that are within their competence, considering their level of education, training, and expertise."

This guidelines document was developed by ASHA's Working Group on Acoustics in Educational Settings. It was approved by ASHA's Legislative Council in ____. Members of the Working Group on Acoustics in Educational Settings include Karen A. Anderson, Susan J. Brannen (vice president for professional practices in audiology, 2001–2003), Carl C. Crandell (co-chair), Peggy B. Nelson, Anne Seltz, Joseph Smaldino (co-chair), and Evelyn J. Williams, (ex officio).

Decades of research on the topic of room acoustics and the effect of poor acoustics on listening and learning in the classroom have lead to certain tenets concerning classroom acoustics (Crandell & Smaldino, 1999; Nelson, 2000).

1. There are children in every classroom, especially in the early grades that either cannot hear well and/or cannot process speech and language well.
2. Not hearing and/or processing well negatively impacts student listening and learning, especially learning to read.
3. Low teacher voice level, background excessive noise level and excessive reverberation exacerbate listening and learning problems.

4. Improvement in classroom acoustics may require solutions involving architectural design, and/or acoustical modifications, and in special cases, hearing assistive technologies.

These tenets are so important, that they have formed the basis for guidelines and standards designed to ensure adequate acoustics for listening and learning. In 1995 the American Speech-Language-Hearing Association (ASHA) published "Position Statement and Guidelines for Acoustics in Educational Settings," that called for background noise levels not to exceed 30 dBA, reverberation times not to exceed 0.4 seconds or less, and an overall teacher signal-to-noise ratio (SNR) of + 15 dB. Generally, these specifications were confirmed in 2002 when the American National Standards Institute (ANSI) published "ANSI S12.60-2002 Acoustical Performance Criteria, Design Requirements and Guidelines for Schools" (ANSI, 2002), which, based on room size, recommends that background noise level not to exceed 35 dBA, reverberation time (RT) not to exceed 0.6-0.7 seconds, and a SNR of +15 dB.

It is clear that audiologists and acoustical consultants can and should work closely together in order to accomplish improvements to acoustic conditions in schools. Since guidelines for this collaboration do not exist, it is appropriate to first consider the complementary roles of audiologists and acoustic consultants by examining a tailored description of each profession:

- *An audiologist is a graduate university-trained professional who is uniquely qualified to provide a comprehensive array of services related to the assessment and audiologic habilitation/rehabilitation of persons with hearing, listening, and balance problems. Some audiologists specialize in the management of hearing, hearing loss, and acoustics within the educational environment* (ASHA, 1996)

- *For the purposes of this document, an acoustical consultant can have a variety of educational backgrounds, such as engineering or physics. The consultant utilizes knowledge of room acoustics, noise control, acoustical isolation, and audio systems to ensure the efficient distribution of desirable sound as well as the suppression of undesirable sound in and around classrooms and other structures* (ANSI, 2002*).*

As can be seen, both professions are concerned with maximizing the desirable perception of wanted acoustic signals in rooms and minimizing undesirable noise and reverberation. This common ground forms the basis for the complementary roles undertaken by each profession in improving classroom acoustics. Table 1 shows the typical professional roles of audiologists and acoustic consultants.

Table 1: Typical professional roles of audiologists and acoustic consultants.

AUDIOLOGIST	ACOUSTIC CONSULTANT
Advocate design	Evaluate design
Survey	Survey (corrective)
Compare to standard	Compare to standard
Recommend modifications	Recommend modifications
	Select materials
Verify physical efficacy	Verify physical efficacy
Verify behavioral efficacy	
(Re)habilitate	
Educate	Educate

Roles of the Audiologist

Advocacy for Classroom Acoustic Issues

While classroom acoustic issues are clearly a part of the audiology scope of practice, audiologists who do not work directly in the schools often feel estranged from the impact of acoustics on listening and learning. Even if the audiologist does not work in the schools, barriers posed by inappropriate room acoustics will affect many of their clients. Additionally, all audiologists live in a school district and therefore, can influence school decision-making. Making the public aware of classroom acoustics issues is a golden opportunity to heighten awareness of the profession of audiology at a local level. Most communities have one or more schools that have issues related to classroom acoustics. The effects of appropriate acoustics on learning can and should be the topic of discussion, particularly if new classroom construction is anticipated.

The acoustics of all learning environments, whether they are traditional classrooms or not, should be a concern during hearing aid dispensing and (re)habilitation of hearing loss. Of all of the professionals working in the area of acoustics, audiologists are most concerned with the impact of acoustics on the communication process. If audiologists choose not to become involved, classroom acoustics will be viewed without a central focus on speech perception issues, especially for the individuals with hearing loss. This involvement is most important when a school district is planning to renovate or build new classrooms. The audiologist must be an advocate for good acoustics and lobby for the application of good acoustical design in the planning and building process.

Survey Classroom Acoustic Conditions

Audiologists are typically the first professionals to identify "at risk" populations or situations. Educational audiologists have long made acoustic assessments of classrooms and student performance within their learning environments. These assessments, however, frequently fail to include formal noise and reverberation measurement and/or behavioral performance measures. The ASHA guidelines and ANSI Standard call for specific procedures to be used to (1) measure background noise levels in dBA, (2) measure or estimate RT, and (3) measure or estimate SNR to describe classroom acoustic conditions. Following measurement or estimation of these acoustic conditions, a comparison must be made to acceptable standards and a determination must be made of the adequacy of the classroom for listening and learning. In addition, it is appropriate to make certain behavioral performance measurements in order to provide a linkage between the acoustic conditions and actual performance of students in the classroom. Some appropriate behavioral performance measures for this purpose are included in Table 2.

Table 2. Examples of behavioral performance measures

Report Inventories (e.g., SIFTER, LIFE, CHILD)
Speech Recognition (e.g. BKB Sentences, HINT, WIPI)
Classroom Performance (e.g., On-task measures, achievement test scores)

Modifications to Improve Acoustic Conditions

Once inadequate acoustics for the purpose of speech perception have been identified in the learning environment, the audiologist must become an advocate for improvement of the acoustic environment. When appropriate, the advocacy can take the form of recommendation of technologies to improve the classroom SNR. Sometimes it involves proper fitting of hearing aids and hearing assistive devices to the student with auditory perception or processing difficulties. Sometimes it means that listening training is recommended for students with difficulties perceiving or processing speech in the classroom environment. In many cases, the audiologist will also recommend the involvement of an acoustical consultant to evaluate and make specific recommendations for physical improvements to accomplish acceptable classroom acoustics.

Establishing Efficacy of Improvements in Classroom Acoustics

Assuming that a survey with recommendations is conducted and that recommendations are effectively implemented, there should be an improvement in acoustic conditions and in the students' ability to perceive the speech of the teacher and other students. This improvement should lead, in turn, to improvements in functional classroom performance. The modifications and improvements, however, must be demonstrated in order to validate the process. If an acoustic consultant has been involved, physical measurements made before and after changes to the acoustic environment serve as physical measures of efficacy. If an acoustic consultant was not involved, the audiologist should complete the pre- and post-physical measurements. In addition to the physical measurements, behavioral measurements in the form of speech recognition scores, teacher or student report forms, changes in student behavior such as "on task behavior," or changes in achievement test scores serve as measures of efficacy. Use of the Speech Transmission Index or other measures of predicted speech recognition might also be employed (Houtgast, T. & Steeneken, 1978). Above all, the audiologist must document that improvements have occurred and that the improvements persist over time.

Habilitation & Rehabilitation Interventions

While improving inappropriate classroom acoustics is a prime objective, we must be aware that the behavioral and psychological effects of exposure to poor classroom acoustics may linger even after the physical acoustic problems are addressed. In order to minimize the long-term sequelae, certain interventions may be appropriate for children in these environments. Table 3 lists some of these possible interventions. The list shown is designed to reinforce the message that physical modifications of the room may not be enough and that habilitation and rehabilitation are key components of a comprehensive approach to minimizing listening and learning barriers in the classroom.

Table 3. Possible (re)habilitative interventions.

Listening Training in the Classroom
Listening Training in the Home
Training in the Use of Clear Speech
Phonological Awareness Training
Counseling for Good Listening (teacher, students, parents)
Visual Communication Training
Communication Repair Strategy Training
Auditory Verbal Training
Monitoring Effectiveness of Hearing Aids or Hearing Assistive Technologies
Monitoring Classroom Noise Management
Using Quiet Areas in a Classroom Effectively

Education About Classroom Acoustic Issues

The negative impact of poor classroom acoustics is not self-evident to teachers, administrators, parents or the public. Unless brought to their attention, acoustic barriers to listening and learning in the classroom are typically ignored. Audiologists must take responsibility for their own involvement, which could include (1) developing primers on room acoustics and/or the effects of acoustics on listening and learning, (2) acting as a resource person for teachers, parents, principals and administrators, and (3) playing an active role in disseminating information concerning classroom acoustics to the general public and policymakers.

Roles of the Acoustic Consultant

There are two ways acoustical consultants may be involved in classroom acoustics. The first is during the design process for new building construction and the second is in corrective work for existing classrooms.

New Construction

The architectural team responsible for the design of a new school building often employs acoustical consultants. Acoustical consultants may be employed to work on many areas of a new school building including but not limited to the auditorium, music rehearsal spaces, gymnasium, natatorium, and cafeteria, in addition to classrooms. The scope of services for these spaces includes interior room acoustics, interior and exterior acoustical isolation, mechanical system noise control, and performance sound reinforcement system design.

For classrooms, the consulting process includes evaluating the design for the interior room acoustics, interior and exterior acoustical isolation, and mechanical system noise control. As a rule, acoustical consultants are not asked to design sound reinforcement systems (i.e., sound field amplification) for classrooms.

Interior Room Acoustics: In order to assure appropriate interior room acoustics, acoustical consultants work with the architects to select acceptable wall, ceiling, and floor materials or finishes for the classroom so that the reverberation time of the room meets or exceeds the reverberation design goal specified in the ANSI standard.

Background Sound Levels: To determine background sound levels in a room, various types of design calculations can be performed, supported, whenever necessary, with noise measurements to determine if the ANSI specified background noise level design goal of 35 dBA criteria could be met.

Mechanical Noise: Mechanical system noise accounts for the highest percentage of noise complaints in the United States (ANSI, 2002). An acoustical consultant can calculate sound levels in a classroom using the design documents provided by the mechanical engineers working on the project. If the 35 dBA design criteria is exceeded, sound attenuation devices can be recommended so that the design goal is met. Mechanical systems for classrooms fall into two categories:

Individual Units: It is easy and inexpensive to install unit ventilators in a classroom. A unit ventilator is a stand-alone unit that contains a fan and may also contain a compressor. Discharged air comes out the top and the intake is usually at the bottom. The best way to minimize sound from stand alone units is to build a closet around them. The supply air would be ducted out of the top to ceiling diffusers. The return air back to the unit would be through a lined shaft inside the closet. The walls and doors must be adequately sealed. This may increase the installed cost of each unit, but will significantly reduce sound levels.

Central System: A central mechanical system supplies air to a classroom through ductwork from a large air handling unit that serves many rooms. If designed carefully (i.e., locating units properly and using attenuation devices such as duct liners or sound attenuators) the sound in the classroom will be minimal. This method can make it easier to control noise since the units are not in the rooms themselves.

<u>Exterior Noise</u>: Exterior noise also contributes to the background sound in a classroom. If the building is in a high noise level area, such as close to an airport or major highway, noise isolation or performance of exterior windows and wall sections can be examined to ensure that the maximum background sound level is met inside the room. This may also require measuring sound levels at the potential site of a new school. More important, correct sound insulation design of the external walls and roof assembly needs to be assured.

<u>Partition Design:</u> Partitions between the classroom and adjacent areas should be designed or upgraded to achieve Sound Transmission Class (STC) ratings as recommended by the ANSI standard. The STC is a single number rating derived from sound transmission loss values and provides a measure of the sound insulation performance of a partition with a defined design configuration. The higher the value, the more the partition attenuates sound. The ANSI standard recommends a rating of 50 STC between classrooms, 45 STC between classrooms and corridors,

and 60 STC between classrooms and high noise level rooms, like mechanical rooms or music rehearsal rooms. To achieve these ratings, the walls must be sealed to the underside of the structure above. Walls that stop just past acoustic tile ceilings will not achieve these ratings because the sound will travel through the acoustic tile ceiling, over the wall, and through the acoustic tile ceiling on the other side.

The information on the interior finishes, partitions and window details, and mechanical system modifications should be given to the design team so that they can be incorporated into the final design documents for the building.

Corrective Work

If problems are noted in a classroom, an acoustical consultant may be employed by a variety of clients including the school district (possibly through the work of an audiologist), the architect or engineer, or in more extreme cases, by litigation. In these instances, an acoustical consultant will evaluate existing conditions in the classrooms, usually performing acoustical testing to determine exact acoustic parameters of the room. The results of the testing are compared to the ANSI standard reverberation time, background noise levels, and sound insulation criteria for wall, floor, and ceiling assemblies and a determination is made to determine if corrective action is needed. Once existing conditions are quantified, and a determination of corrective need is made, recommendations can be devised to meet acceptable criteria to the extent practicable.

Administrators in schools where classroom acoustics cannot be appropriately corrected and those who want to enhance the SNR of verbal instruction have considered using hearing assistive technology as a means to address inadequate acoustics in learning environments. This is a reasonable solution in some situations and for some student populations. Even in classrooms where the acoustic criteria have been met, it is important to realize that for some students with hearing loss, additional signal enhancement technology may be required. Please refer to the Appendix for a review of the benefits of hearing assistive technology for students with normal hearing and hearing loss in relation to existing levels of background noise, reverberation in a classroom, and SNR.

This document along with its companion documents *Acoustics in Educational Settings: Position Statement* (ASHA, n.d. – a) and *Acoustics in Educational Settings: Technical Report* (ASHA, n.d. – b) can be used by audiologists and other professionals to facilitate improved acoustics for all students. Working together, the audiologist and acoustic consultant complement each other and assist in identifying and documenting unacceptable acoustic conditions, specifying acoustic modifications and materials, installing and testing the adequacy of an installation from a physical measurement point of view, and finally documenting behaviorally that a physical modification results in improved speech perception.

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Appendix

Use of Hearing Assistive Technology by Children to Overcome Acoustic Barriers to Classroom Learning

It is evident that children with hearing loss require special consideration of their listening needs in a classroom setting if they are to access verbal instruction as fully as possible within the limitations of their hearing loss. Careful monitoring of the use of teacher and supplementary FM microphones is necessary to ensure that the full spoken message is conveyed to the child using the FM system. The use of an FM system alone will not adequately address these listening needs when a classroom is noisy or reverberant. For the young listener with hearing loss, the combination of adequate classroom acoustics and FM technology is necessary to assure that noise will not be a barrier to learning within a classroom. The use of a sound field classroom amplification system in a classroom that meets the ANSI acoustics standards may benefit children with normal hearing and the teacher. However, the use of this technology alone cannot be considered appropriate to meet the needs of students with hearing loss, whether they are hearing aid or cochlear implant users.

Children With Normal Hearing

Sound field amplification improves the signal-to-noise ratio (SNR) in a classroom by using a microphone transmitter to amplify the teacher's voice over low levels of background noise and deliver this signal to one or more speakers in the ceiling or along the walls of a classroom. Sound field amplification technology has been used in classrooms since the inception of the Mainstream Amplification Resource Room (MARRS) Project in 1978. A National Distribution Network project for 15 years, MARRS actively distributed information throughout the 1980s and early 1990s to educators describing the benefits of sound field amplification use for children with normal hearing and mild hearing loss. The MARRS Project research indicated that amplification of the teacher's voice in the classroom resulted in greater academic achievement at a faster rate for all learners, at 1/10th the cost of instruction in unamplified resource rooms for identified children with hearing loss (Sarff, 1981; Ray, 1987, 1989,1992; Ray, Sarff, & Glassford, 1984).

Subsequent researchers found that the use of sound field amplification in the classroom provides significant improvement in word and sentence recognition for typical students with normal hearing (Crandell & Bess, 1986, Jones, Berg, & Viehweg, 1989; Crandell, 1993), students with developmental disabilities (Flexer, Millin, & Brown, 1990), non-native English learners (Crandell, 1996; Hodgson & Montgomery, 1994; Crandell & Smaldino, 1996b; Mayo, Florentine, & Buus, 1997; Eriks-Brophy & Ayukawa, 2000; Nelson & Soli, 2000), and for students with minimal degrees of hearing loss (Jones, Berg, & Viehweg, 1989; Neuss, Blair, & Viehweg, 1991). In addition to improvements in speech perception, consistent use of amplification of the teacher's voice has been found to improve the academic performance of typical learners (Sarff, 1981; Flexer, 1989; Osbourn, VonderEmbse, & Graves, 1989; Ray, Sarff, & Glassford, 1984; Flexer, 1992; Ray, 1992; Zabel & Tabor, 1993; Flexer, Richards, & Buie, 1993; Rosenberg, Blake-Rahter, Allen, & Redmond, 1994) and learners with minimal hearing loss or histories of fluctuating middle ear effusion (Schermer, 1991; Flexer, Richards, & Buie, 1993). Improved on-task or listening behaviors have been indicated as a benefit of sound field amplification use for preschool, primary, and secondary school students (Benafield, 1990; Gilman & Danzer, 1989; Allen & Patton, 1990).

The use of sound field amplification can improve the SNR of listeners in a typical classroom setting, thereby improving speech perception and learning. Sound field amplification can overcome the effects of low level background noise and speech degradation due to student-teacher distance; however, this technology cannot overcome the smearing effects of inappropriate levels of reverberation. Therefore, sound field infrared or FM technology can be one tool that may help to improve the SNR to the desired +15 level in classrooms with reverberation times of 0.6 seconds or lower. When appropriate levels of reverberation and low background noise are present in a classroom, this technology may be beneficial in addressing the listening needs of children with normal hearing, those with minimal or fluctuating degrees of hearing loss, those with developmental learning problems, or students who are non-native English speakers.

<u>Children With Hearing Loss</u>

As has been discussed, classrooms are recognized as reverberant and noisy learning environments with typical levels of noise ranging from 53–74 dB (Finitzo-Hieber, 1988). Hearing instruments have been found to be ineffective in providing benefit to speech perception in environments with noise in excess of 60 dBA (Duquesnoy & Plomp, 1983). Every single dB gain in SNR results in an increase in the intelligibility of speech by listeners with hearing loss (Duquesnoy & Plomp, 1983). A SNR of +15 or better is recognized as being necessary to assure that noise will not be a barrier to learning within a classroom (ANSI Standard, 2002).

Although it is possible to achieve a +15 SNR in a classroom through use of adequate acoustic treatment and noise control, it cannot be assumed that adequate acoustics will overcome the effects of degradation of speech across distance and interference of minimal or fluctuating noise for children with hearing loss. In addition to a highly favorable SNR, studies have indicated that the child with hearing loss also requires the primary signal to be present within the critical listening distance (Picard & Lefrancois, 1986, Crandell, Holmes, Flexer, & Payne, 1998; American Speech-Language-Hearing Association, 2002; Anderson & Goldstein, 2003; Anderson, Colodzin, Iglehart, Goldstein, 2003) or in an environment that has a reverberation time of less than 0.4 seconds (Blair, Myrup, & Viehweg, 1989; Noe, Davidson, & Mishler, 1997; Iglehart, 2003) if true access to verbal instruction is to be achieved.

Listeners consistently have a higher level of speech perception performance when ear-level or desktop FM devices are used, whether they have hearing that is normal (Nabelek & Donahue, 1986; Nabelek, Donahue, & Letowski, 1986; Smith, McConnel, Walter, & Miller, 1985; Blake, Field, Foster, Platt, & Wertz, 1991), whether they are hearing aid users (Picard & Lefrancois, 1986; Blair, et al., 1989; Benoit, 1989; Moeller, Donaghy, Beuchaine, Lewis, & Stelmachowicz, 1996; Noe, et al., 1997; Boothroyd & Iglehart, 1998; Toe, 1999; Anderson & Goldstein, 2003; Anderson, et al., 2003) or whether they are cochlear implant users (Foster, Brackett, & Maxon, 1997; Crandell, et al., 1998; Anderson, et al., 2003). Under classroom acoustic conditions that meet the ANSI standards, the use of an ear level FM system can result in an improvement in word discrimination up to approximately 20% (Picard & Lefrancois, 1986) as long as the individual with hearing loss has a word discrimination ability in quiet of at least 40%–60% (Boothroyd & Iglehart, 1998). An increase of up to 25% improvement in word discrimination can occur under ideal reverberation conditions (i.e., 0.3 RT) (Boothroyd & Iglehart, 1998). Listeners with severe to profound hearing loss that have word discrimination scores in quiet above 20% can benefit from the use of personal FM by an increased attention to verbal instruction and a decrease in dependency on note taking or cued/signed supplemental information (Toe, 1999). The use of desktop FM can provide equal benefit to speech perception of listeners with mild to moderate-severe hearing loss that have word discrimination scores in quiet above 75% (Anderson, et al., 2003).

Listeners who are cochlear implant users need a minimum of +10 SNR to function communicatively (Fetterman & Domico, 2002) but require at least a +15 SNR if they are to be expected to access verbal instruction (Hamzavi, Franz, Baumgartner, & Gstoettner, 2001), even in a classroom that meets the ANSI acoustic standards. An improvement of approximately 15–20% in word discrimination scores may be achieved by children using implants in +15 SNR conditions as compared to +10 SNR (Hamzavi, et al., 2001). Enhancement of SNR provided by a desktop FM device can improve word discrimination scores by approximately 20% (Foster, Brackett, & Maxon, 1997). Cochlear implant listeners with word discrimination scores of 60% or less may perform better with the FM signal input into their speech processor directly rather than via a desktop FM device (Anderson, et al., 2003).

Research investigations have determined that the use of classroom sound field amplification provides no significant benefit over hearing aids alone (Anderson & Goldstein, 2003; Anderson et al., 2003) or cochlear implants alone (Crandell, et al, 1998; Anderson, et al., 2003) unless the reverberation time is very low (Blair, et al., 1989; Noe, et al. 1997; Iglehart, 2003). Even in a low reverberation environment performance is better with devices presenting the improved SNR signal within the critical listening distance than presentation by soundfield FM or infrared devices presenting the teacher’s voice throughout the classroom (Nabelek & Donahue, 1986; Nabelek, et al., 1986; Noe, et al., 1997).

Research indicates that the use of hearing assistive technology (e.g., FM systems, sound field amplification) for children with normal hearing, children with hearing loss or listening problems, as well as non-native English learners is often beneficial. This is true in classrooms with appropriate acoustics as well as those that do not meet the ANSI acoustical criteria. The use of hearing assistive technology must be considered on and individual and classroom-by-classroom basis. Audiologists are uniquely qualified to evaluate the need for and provide expertise in recommending, selecting, and fitting hearing assistive technologies and should be consulted prior to the application of these devices and systems.

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