SOUND REINFORCEMENT FOR CLASSROOMS: A CLEAR NEED WITH CLEAR BENEFITS

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The art and science of classroom video projection has come a long way in the past decade. The size, weight, and price of projectors have decreased dramatically, while brightness, resolution, and connectivity options have all increased just as dramatically. These developments, in turn, have made it possible for more classrooms to incorporate rich media presentations as an everyday part of their curriculum, displaying video content, still images, desktop and notebook computer screens, and Web pages.

These advances in video projection have come at such a rapid pace that we tend to forget video is only one-half of the teaching equation. The other half, audio, has only recently been accorded the importance it deserves, as more and more manufacturers are introducing sound reinforcement systems for classrooms.

It may surprise you to learn that listening activity constitutes 45%[1] of the time a child spends in class each day, on average. As much as we depend on our sense of sight to communicate information about the world around us, our sense of hearing is just as essential to the development of language and communication skills, particularly when learning to read and speak.

It is easy to understand how poor room acoustics can impair a child's ability to progress in verbal communication as he or she moves through primary school. Mastering a language is all about repetitive listening and speech exercises to recognize and memorize arrangements of vowels and consonants, not to mention inflections. Any impairments to the classroom acoustic environment make it that much more difficult to understand the teacher and slow down the process.

Students that have trouble hearing teachers also score lower on standardized tests. Over time, this can lead to negative attitudinal shifts that adversely impact classroom instruction[2]. A student that falls behind his or her peers in accomplishing learning tasks may give up and withdraw from active classroom participation, or become disruptive, thereby affecting the performance of other students.

Clearly, it is in the best interests of both students and teachers to ensure an optimal acoustic environment for classroom instruction. To accomplish that, some sort of sound reinforcement system is required, as the typical classroom size and its ambient noise levels are too much for the average teacher to overcome when using a normal speaking voice. To better understand why, let's briefly explore some of the science behind the transmission of sound waves.

THE BASICS

Sound waves and light waves may have vastly different characteristic frequencies, but they behave in much the same way as they travel through space: They diffuse, or spread out at increasingly larger angles from their point of origin. The principle of physics that explains this behavior is known as the inverse square law, and it is just as useful to determine audio levels at a given distance from a source of sound waves, as it is to predict the brightness of a projected image at a given distance. In essence, the inverse square law shows that loudness drops by an inverse square function as the distance between the listener and source of sound increases.

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[1] *Facilitating Classroom Listening: A Handbook for Teachers of Normal and Hard of Hearing Students.* Berg, F.S. (1987) College-Hill Press/Little Brown.

[2] "Language, speech, and hearing services in schools," Palmer, C. *American Speech-Language-Hearing Association* (July 1997)

This rapid drop-off in sound levels assumes a perfect acoustical space, free of reverberation (sound wave echoes). In real life, all classrooms exhibit reverberation, which helps to overcome some of this drop-off in speech levels.

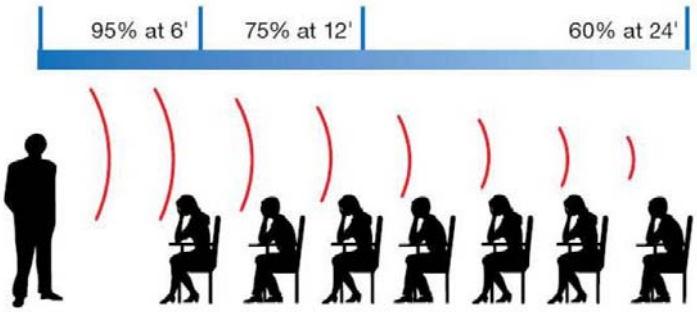

Figure 1. This illustration clearly shows how rapidly sound levels diminish with distance.

Here's a graphic example of how sound levels decline over distance: Let's say a student is sitting six feet from a teacher, and the level of sound at that desk is 95% of the teacher's voice level. At the third row of desks, the distance to the teacher is double the distance to the first row, or 12 feet. The sound level has now dropped by 20% from the first row.

By the time the teacher's voice has made it to the back row of seats, located 24' distant, its level has declined by an additional 15%. With additional sound-absorbing surfaces in the room, such as thicker carpet, window drapes, or wall treatments, the teacher's voice could easily be attenuated by 50% or more by the time it reaches the rear of the room. The acoustics of the room also pose challenges. Classrooms are typically constructed with hard walls and floors, as these are easiest to clean and maintain. But such surfaces create problems of their own, such as uneven frequency response from sound waves reflecting off their surfaces.

The majority of human speech communication occurs within a narrow range of frequencies, typically from 300 Hz (low) to about 3 kHz (high). Depending on where a student is seated, speech sounds reflecting from walls and other surfaces may be attenuated within this range of frequencies. Also, speech may be absorbed or dampened by other objects in the classroom, such as carpeting and drapes.

Room acoustics are one issue; ambient noise is quite another! Room noise can come from any number of internal and external sources, including chairs moving, keyboards, computer fans, printers, hum from fluorescent lights, street noise, and any appliances such as motors, fans, the rustling of papers, and even low-level conversations between students.

The American National Standards Institute (ANSI S12.60-2002) has determined that the maximum ambient noise level for a classroom should not exceed 35 decibels, 'A' weighted.[3] To overcome both internal and external noise, the American Speech-Language-Hearing Association (ASHA) recommends a minimum signal-to-noise (SNR) ratio of 15 dB (the level of the teacher's voice over ambient noise).

Reverberance is also a challenge. Hard walls and floors create reverberating sound waves, which can cancel each other out and roll-off high frequency audio information. This in turn makes it that much harder for a student to understand a complex instruction or hear the specific pronunciation of a word or words. Studies have shown that the typical classroom can exhibit reverberation times as long as 1.25 seconds[4], almost four times that of the ASHA recommendation of .4 seconds.

[3] "Group amplification in schools for the hearing impaired," F.H. Bess, J.S. Sinclair, and D. Riggs, *Ear and Hearing V* (1984)
[4] "The effects of classroom amplification on children with normal hearing," C. Crandell, *Educational Audiology Monograph II* (1991)

Student Reading	56 dBA
Working At Tables	65 dBA
Group Activity	73 dBA
Room HVAC	28-48 dBA
Exterior Noise, Infiltrated	30-40 dBA
Teacher's Voice, Unamplified	65-75 dBA

Figure 2. Typical sound levels measured in a classroom. (Source: "High Performance Schools," Gertel, McCarty, Schoff. *Educational Faculty Planner*, Vol. 39, No. 3)

Not every student hears the same way. There may be physical limitations to hearing, such as limited frequency response in the ear, or partial deafness. Or, the student may be trying to learn a second language, one with vastly different combinations of vowels, consonants, and inflections. The student may have a learning disorder, such as an attention deficit. All of these students are at risk when speech communication is impaired in a classroom.

Hearing impaired students may already have been fitted with some sort of assisted listening device. These devices are fine for normal, face-to-face communication and small group instruction. But the effects of sound wave propagation create just as much of a challenge for this group, as their assisted listening equipment only places them on a par with other students of normal hearing acuity. Thus, the effects of distance, reverberation, and ambient noise are felt just the same.

AUDIO REINFORCEMENT SOLUTIONS

Clearly, audio reinforcement in classrooms is an excellent idea and one that yields immediate dividends. The U.S. Department of Education's Mainstream Amplification Resource Room Study (MARRS), conducted in 1984, showed that students in grades K-6 with normal learning potential and minimal hearing loss earned significantly higher reading comprehension test scores within weeks of using a sound reinforcement system.

MARSS also revealed that, with sound reinforcement, classroom management was more effective, participation increased, and referrals to special education classes dropped by as much as 43% over a five-year period. More significantly, teacher absences due to strained vocal chords were reduced from 15% to 2-3% of all absences within one year.

A 2003 Trost Elementary School (Oregon) study showed that, after adding sound reinforcement to classrooms, students scored between 21% to 35% higher on standardized state literacy and skills assessment tests, and also demonstrated a 35% increase in fourth and fifth grade words-per-minute reading comprehension. In addition, Trost calculated a 72% decrease in teacher task redirections with voice amplification, along with a 43% decrease in off-task student behavior.

The key is to use speech and sound reinforcement appropriately. The Acoustical Society of America (ASA) recommends audio reinforcement only when reverberation times are less than .6 seconds, and only to maintain the 15 dB SNR target. ASA cautions against routinely using sound reinforcement in small classrooms, but strongly urges that new and renovated small classrooms fully conform to ANSI 12.60-2002 specifications.

There are numerous ways to provide sound reinforcement. **Assisted listening devices** work very well in this regard, as each student has a personal receiver with optimized volume settings. However, assisted listening systems are expensive to install and maintain, and each receiver adds incremental costs and maintenance issues. For students who already use such a device, there is no benefit – only redundancy.

Audio reinforcement systems that consist of **simple arrays of loudspeakers** are cost effective, but are subject to the same issues with sound absorption, high-frequency roll-off, and reverberation as an unamplified speaking voice – they're just louder. These systems typically use a wireless (RF or infrared) microphone, handheld or lapel, and speakers mounted on the wall or inside of it using architectural enclosures.

Echoes and frequency equalization problems are corrected by using external delay lines and multiband graphic equalizers. These will add to the cost of the room and must be calibrated and maintained, but will provide excellent results. Delay lines make it possible to increase the number of speakers in arrays and provide complete sound field coverage.

What about using the **internal speakers in a classroom projector**? This is certainly a cost-effective and simple approach that appeals to primary schools, where the projector is frequently moved from room to room. However, projector speakers are not located in an optimal position for all students, meaning that (once again) some students will hear audio playback better than others, and reverberation and equalization problems are still present.

Figure 3. Example of a unidirectional classroom sound reinforcement system that easily attaches to a conventional ceiling projector mount. (Source: Epson)

Another option is to employ a **ceiling-mounted sound reinforcement system** that mounts with a projector on a ceiling bracket. The speakers in this system are angled downwards and provide coverage in four directions, ensuring that all students are facing at least one speaker. The directional speaker arrays provide full room coverage and minimize reverberations.

The advantage to this design is that the projector mount is usually closer to the centerline of the room and high enough to provide coverage all the way to the last row of seats. It can provide both speech and playback audio reinforcement, but does not require an architectural mounting solution and is relatively easy and inexpensive to install and maintain.

CONCLUSION

Sound reinforcement in classrooms is clearly an idea whose time has arrived. Used as a stand-alone method for teacher voice amplification, or in concert with prerecorded video and audio playback, sound reinforcement clearly enhances the learning experience for students, reduces vocal stress and fatigue for teachers, and has improved test and comprehension scores everywhere it has been implemented.

The key is to choose a system that is affordable, simple to install and operate, requires little maintenance, and provides focused, uniform coverage of all seating and working areas in the classroom. Of course, any of the sound reinforcement systems mentioned will work better with acoustic upgrades to the classroom, including carpet and wall treatments to deaden reverberation and reduce external noise. There is no substitute for a quiet teaching environment that is free of distracting sounds!