Classroom Sound Distribution

Classroom sound distribution is a low-tech economical way to improve students' ability to attend to spoken instruction in the classroom. An increasing body of peer-reviewed scientific evidence has shown global performance improvement in young learners when sound distribution equipment is used correctly in the classroom. In this brief article, we will review fundamentals of acoustics and physiology that can help us understand problems in the typical classroom environment that sound distribution strategies can help to overcome.

To immediately acquaint yourself with the problem being discussed try to remember an instance when you were at a lecture or an event and were listening intently when, half way through, the PA system failed. After a minute of fussing the speaker continued with the presentation but with a noticeable decrease in quality stemming from both the speaker's strained efforts to project their message without amplification and the extra effort you had to put into listening. Well designed and executed studies that measure student learning show measurable improvements in student performance when they can hear easily. The substandard condition you experienced and found frustrating is the default condition for children in classrooms today.

Now imagine a classroom with only one light and only one source of heat, like a fireplace. Much of the classroom away from the fireplace will be too poorly lit to easily work in and too cool to feel comfortable. We do not allow classrooms to be built to such a low standard. These examples show why so many feel sound distribution is an idea whose time has come.

Acoustic problems in a typical classroom

A properly used sound distribution system creates an even sound field for instructional content around the classroom. This is distinctly different than the situation in a typical classroom. In a typical classroom, sound volume decreases in intensity as it travels away from the teacher, and students in the front row have a distinctly different learning experience than those in the back row. A student in the front row will hear the teacher's voice above the level of the background noise in the classroom, whereas a student in the back of the classroom may hear the teacher's voice at a level below the background noise. It has been unequivocally demonstrated that students in the back row will not perform as well because of this condition.

Students in the front row will also hear a clearer, as well as a louder signal than students in the back row. This is because the signals heard by students in the back row are blurred by reflections off of walls, floor, and ceiling that arrive out of phase with the directly-received speech signal and each other. This decreases the intelligibility of all that children in the back row hear compared to students in the front row. In short, students in the front row have a louder and clearer signal to learn from than students in the back row.

The goal of a sound distribution system is to place speakers around the classroom so that no student is more than 8 feet from a sound source. Although the speakers each put out sound no louder than the teacher's natural voice they

give students access to a loud and clear signal as if they are within 8 feet of the teacher regardless of where they are seated in the classroom. It is difficult for a single loudspeaker to do this well because it has to be turned up much louder than the teacher's voice to maintain a good sound level in the rear of the classroom. Also, a single speaker cannot overcome the blurring effects of reverberation that occur farther from the sound source in all classrooms with high reverberation.

What is reverberation?

Reverberation is the slow decay of sound that results from echoes of sound in an enclosed space. Reverberation time is the time it takes for sound intensity to decay by 60 decibels. A word spoken in a plowed field makes no echo because the sound reflects minimally off of the plowed earth and not at all from the air. The sound intensity falls by a factor of 4 each time the distance from the speaker is doubled. These are known as "free field" acoustic conditions. It is easy to understand speech in a field where the reverberation time is zero. In an enclosed room the sound intensity of a spoken word is sustained by echoes from the surfaces in the room. The echoes of one word linger and interfere with the ability to discern the next. This results in decreased intelligibility of spoken words in rooms with increasing reverberation. Rooms for instruction are ideally designed with sound absorbing materials to lower reverberation as in a living room which has a reverberation time of 0.4 seconds. This improves intelligibility but can be expensive. Typical classrooms with block walls and bare floor will average reverberation times of 1 second. A reverberation time of 0.6 seconds in classrooms is an achievable ideal.

The poorest classroom from an acoustical point of view is the classic plaster walled and terrazzo floor room with a high plaster ceiling. Rooms like these reverberate so much you can hear your voice echo and the echo of clapped hands will snap. Speaking louder to improve intelligibility in such a reverberant environment actually decreases the ability of listeners to understand because as voice volume increases the low frequency parts of speech increase in volume more than higher frequencies that are important for speech discrimination. The low frequency sounds reverberate longer too, which masks the high frequency content of words even more. We have all experienced the frustration of hearing but not understanding amplified announcements in reverberant environments like train stations, churches and airports.

Background noise in classrooms

Background noise, like reverberation, competes with the teacher's voice and can have many sources in the classroom. Background noise should be controlled so the teacher's voice can be heard 15 decibels louder than the background noise (35 decibels= a whisper, 50-55 decibels= normal speaking voice, 65 decibels= projected or maximum voice level).

Sources of background noise include:

-heating, ventilating, air conditioning
-adjacent rooms, corridors
-streets, lawn mowers
-student noise from furniture, shoes

Background noise levels in occupied classrooms average 50 decibels. Most unoccupied classrooms have noise levels of 40 to 50 decibels. This means that teachers must drive their voices to often unsustainable maximum levels (65 decibels) to be heard clearly. This results in vocal fatigue, absenteeism and is a major factor influencing teacher retirement. Teachers have more voice problems than any other professional group.

Current building standards have put the burden on school designers to lower noise levels in unoccupied classrooms to 35 decibels to allow the teacher's voice to be heard clearly. This is very expensive from a design and construction standpoint but is a good investment of funds. School designers are looking with great interest at sound distribution as a more economical way to meet the acoustical needs of students than redesign of existing classrooms or expensive primary design of older ones. In Delaware, for example, new school construction standards adopted in 2006 specify a +15 decibel speech to noise ratio in all areas of the classroom and leave it up to school designers to decide how they will meet the standard and stay in budget.

What hardware makes up a sound distribution system?

From a hardware standpoint, the sound distribution system consists of a wireless microphone worn by the teacher, an amplifier, and speakers. Simple but particular needs that arise in the classroom have resulted in straightforward but powerful refinements that increase usability in the classroom setting. These refinements include features such as: 1) additional microphones for students to allow student voices to be singled out and distributed, 2) compatibility with FM hearing aid systems used by hearing impaired students that allow the teacher's voice to be channeled to the speakers and the hearing aid through a single microphone, 3) individual speaker volume controls to adapt the system to unavoidable noise sources that may affect only one area of the classroom, and 4) infrared rather than FM communication between the teacher's microphone and the amplifier to prevent the signal from effecting other systems in use in nearby rooms. These refinements push the price of systems specially designed for classroom use to the $1100 - $1700.

Some systems use only one speaker. These may be good alternative if the system must be moved frequently during the school day or year. Because there is only one and not four speakers the cost of these systems may be lower, but cost alone should not dictate their use over multi-speaker equipment if portability is not a priority.

Used properly, it is difficult to detect amplification in a classroom with a sound field system in use because speaker volume is generally no louder than the teacher's natural voice. What is evident is that the teacher is easily heard in all areas of the room without ever straining to hear. Also noticeable is the lack of voice straining that comes from the teacher's voice projection. Teachers who use sound distribution quickly learn to teach and control the classroom with a calm and unstressed voice. They also experience less vocal fatigue and have fewer absences related to voice failure.

Youth and speech understanding in noise

Children have more difficulty than adults in understanding speech in noise due to slow central maturation of central hearing pathways that continues until age 15. At that age students will score as well as adults on word identification tasks with background noise. To score as well as adults at earlier ages children must hear the test words louder relative to the background noise than adults. The ability to suppress background noise when listening to a voice stream is called the "precedence effect" in hearing research. It is not present at birth. A 5 year old can localize sounds better than voices but continues to hear echoes as independent non-suppressed competing sounds that make reverberation and noise a greater problem for him than adults. Understanding the precedence effect we can see how a listening environment that seems acceptable to adults may be difficult for a child.

The human hearing physiology above is carefully studied and controls for problems of abnormal hearing, cognition and language unfamiliarity. In reality, cognitive problems, hearing loss and language unfamiliarity are common among today's students. In a first grade classroom 15-20% of students may have mild hearing loss on any given day because of middle ear infection, pressure or fluid related to eustachean tube dysfunction from colds or allergies. 10 to 15% of children will have some degree of mild learning disability and for 5 to 11% English will be their second language. All of these children have learning challenges in acoustically optimal conditions that are compounded in suboptimal acoustic environments.

Barriers to adoption of sound field equipment

Despite the studied benefits of sound field use in classrooms around the globe we should be cautious when quickly adopting it at an administrative level because teachers and not administrators are the end users of the equipment. Providing equipment to teachers and demanding its use without proper education is likely to be met with resistance just as any unexplained demand for change will. School or district wide implementation should be preceded by teacher education sufficient to insure understanding of the unmet needs of students and the benefits to students and teachers that can come from proper system use. Failure to grasp these concepts or to misunderstand proper use of the system will lead to teacher resistance that can delay student benefit.

Schools considering adopting equipment should solicit experienced help with staff presentations at the time funding for the technology is planned. This pre-implementation education need has not been adequately addressed by manufacturers. One group dedicated to developing instructional materials for teachers in school systems adopting sound field technology is The Institute for Enhanced Classroom Hearing.

School officials do not typically warm to the idea of large capital expenditures as they are constantly balancing many budget priorities. Most of their budget is taken by salaries and the rest is squeezed by the expensive business of building and staffing new classrooms to maintain or hopefully to decrease class size. There is, however, pressure to measurably improve student performance. Sound distribution use has proven effective in achieving performance improvement at a fraction of the cost of curriculum change, staff increases and new classroom construction. Other efficiencies have been observed with sound field use such as decreased special education referral and decreased teacher absenteeism.