CLASSROOM HEARING AND SOUND ENHANCEMENT

A White Paper of Audio Enhancement Co.

October 2009

CONTENTS

Importance of Hearing in the Classroom

A child's ability to hear clearly is essential to the learning process in a public school classroom. Typical U.S. classrooms are audio-visual environments where knowledge is imparted through visual and spoken instruction.

As much as 80% of what students learn is provided by the teacher's spoken communication. That is often fast-paced, delivered from a distance, and demands constant detailed listening. Students must be able to hear the teacher for learning to occur.

A basic assumption about the classroom is that children can hear clearly and will focus on the teacher's speech. But today, in thousands of classrooms across America, millions of children are not hearing their teacher' voice. They're not even hearing their fellow students' voices.

The ability to hear clearly is blocked in many classrooms by barriers created by inadequate consideration of acoustical factors in the design of the room -- even in today's modern schools. And while good design practice has achieved many of the goals of today's educators, there have been no comprehensive and consistent criteria for creating and measuring good acoustic design.

The barriers to successful hearing in classroom environments are both physical and physiological. Confronting those barriers and overcoming them is the classroom challenge.

That is why a group of acousticians in the Acoustical Society of America (ASA) organized in the late nineties to develop a standard for acoustical design of classrooms.

The ANSI / ASA Standard for Classroom Acoustical Design

In 2002, the ASA introduced the ANSI/ASA Standard S12.60 for "Acoustical Performance . . . for Schools," and it has brought clarity and much-needed attention to the proper acoustical design of classrooms. Its effects are to lower sound-masking background noise levels, minimize speech-muddling reverberation, and reduce disturbing noise intrusion from outside. Classrooms designed to the ASA Standard criteria provide a better learning environment than non-complying rooms.

However, there are some shortcomings in the Standard that still leave students unable to clearly hear the teacher's voice -- especially those students near the rear of the room or behind the teacher in more circular seating arrangements..

In addition, the ASA has taken an obdurate position against the use of "amplification" of the teacher's voice, thereby ignoring the potential for today's electronic technology to remedy the condition.

After six years, the Standard has now come up for review and revision. A new Working Group has been formed and is currently meeting. It is expected these shortcomings will be corrected.

The Noise Problem and SNR

It is difficult to hear when there is a lot of noise. No one disputes this truth. What is in contention is "how much is a lot?" and "where does classroom noise come from?"

The objectionable quantity of noise is best defined in terms of the acoustical criterion of "Signal-to-Noise Ratio" (SNR) -- also called speech-to-noise ratio. SNR is the relationship between the desired auditory signal to all other unwanted sounds – that is, the level of the speaker's voice relative to the "background noise." It is expressed in the acoustical unit of decibels (dB).

Adults with normal hearing require a SNR of approximately +6 dB in order to hear the spoken message as consistently intelligible. For them, the desired signal needs to be about twice as loud as background sounds.

However, children require a much more favorable SNR in order to receive intelligible speech -- approximately +15 dB to +20dB. For them, the desired signal needs to be about 10 times louder than background sounds!

This includes all children, because humans do not develop cognitive maturity until about 14 years, and they are unable to fill gaps in hearing with contextual understanding.

For children with any type of hearing insufficiency, SNR is even more critical. Those include children with inner ear infections which occur in 20% of primary students. It also includes children with auditory processing problems or learning disabilities; children with attention problems or behavior problems; children with developmental disabilities or visual disabilities; and children whose first language is not the language of the speaker.

There is widespread consensus among speech-hearing authorities, audiologists, and acousticians on the importance of providing a **Signal-to-Noise Ratio** of **15 dB**, preferably more, in learning environments for children.

Therefore, the objectionable quantity of background noise becomes defined as that level above which the speaker's voice provides less than a 15 dB difference.

Keep this in mind when we listen to the teacher, whose voice at approximately one meter from her face is about 65 dBA (that is decibels weighted for speech frequencies , called the "A" scale). However, even in well-designed classrooms, students in the seats farthest from the teacher are still not hearing her voice clearly.

The sound level of the teacher's voice diminishes with distance. As the sound waves travel to the back of the classroom, the voice level drops lower and lower, finally to a level where it is masked by the background noise generated within the room. Especially lost in this process are the sounds of the consonants like "s" and "t" and "b" that are so important in defining words. And as noise levels in the room increase, speech intelligibility gradually gets lost.

The sound level of the speaker's voice drops by about 6 dB each time the distance from the speaker doubles. So, the student at the back of a typical classroom hears the teacher's voice at a sound level of 50 dBA or less.

The **maximum allowable background noise**, then, to achieve a SNR = 15, is 50 - 15 = **35 dBA**. This is the level over which the teacher's voice can communicate clearly. And this is the benchmark that has guided the ASA in setting a maximum level for background noise in their ASA Standard.

Noise in the Empty Classroom

The ASA Standard has tried to deal with the noise problem by mandating a maximum background sound level of 35 dBA in an unoccupied classroom -- that is, an empty, non-working classroom.

Noise sources for this condition would be ambient street sounds and the noise generated by the motors, fans and air-movement through ducts of a HVAC system. (Sounds produced in the room by instructional equipment, such as computers, projectors, fume-hoods, an aquarium, or a hamster wheel are excluded from the ASA Standard's requirements -- even tho' they, too, contribute to the background noise.)

Because the architectural acousticians' science is based on physics, they deal only with the physical structure of the unoccupied classroom, and not with dynamic acoustical conditions introduced by the occupants (students, teachers, and instructional equipment). And their limit of 35 dBA deals only with the **empty** classroom.

Noise in the Full "Working" Classroom

But research has now shown that the actual background noise level of a **full** classroom -- that is, a functioning, "working" classroom -- is in excess of 45 dBA – making no longer relevant the ASA-mandated level. Any source of sound above 38 dBA (= 35 + 3) negates the significance of the 35 dBA sound source.

In many climate regions, a very significant investment is required to lower the HVAC noise to the 35 dBA level - while 45 dBA is reasonably and economically achievable. So, these findings clearly show that it is not necessary to invest the additional funds to reach a 35 dBA sound level in the empty classroom.

ASA representatives have disputed these findings. Nevertheless, the research findings are compelling.

Here are some examples of the research that has been reported (after the ASA Standard was issued) on the actual background sound levels in dynamic classrooms of 20 to 30 students:

- The British acoustician Bridget Shields, who has been a pioneer in studying the effects of classroom noise on student performance, reported in 2002 that background sound-pressure levels (SPL) of 56 dBA occurred in a classroom where the students were engaged in "silent reading and writing." It was higher during more general activities. (The background noise level of the empty classroom was 47 dBA.)
- At the San Pascual School in Los Angeles in 2003, in a second-grade classroom of 20 students, using a hand-held sound-level meter about ten feet from the student cluster, the most consistent SPL observed during a 10-minute period of "silent reading" was 48 dBA, with readings fluctuating between 43 and 51 dBA. No one was speaking or moving about. (The background noise level of the empty classroom was 35 dBA.)
- At the Gratts Elementary School in Los Angeles in 2004, a two-day test of recorded sound-pressure levels (SPL)was run in a fourth-grade classroom with 30 students. During general activities, the Leq 60 readings (roughly the "average" level during an hour) were about 65 to 70 dBA. But during these same periods the background sound levels (as defined by L95, measured by the statistical calculation of the sound level that was exceeded more than 95% of the time) ranged between 43 and 52 dBA. (The background noise level of the empty classroom was 42 dBA.)
- Research by acoustical experts in Germany at the University of Bremen, reported in 2006 and later (Oberdorster and Tiesler, "Acoustic Ergonomics of Schools"), showed authoritatively that

sound levels in “working classrooms” were generated by the STUDENTS -- not by building equipment or street noise. (These classrooms were not air-conditioned; nevertheless, unoccupied background noise levels were around 47 dBA.)

Measurements in the German classrooms showed that, when Reverberation Time (RT) was between 0.6 and 0.7 seconds, the "working" background SPL ("Basic SPL" or L95) was between 52 and 57 dBAs. In other classrooms that had superior acoustical characteristics, where RT was less than 0.5 seconds, the background SPL was between 47 and 53 dBA -- about 5 dB lower. And, in these functioning classrooms, the "Working SPL" (Leq) rarely measured under 50 dBA even during quiet work periods of silent reading.

From this evidence, it is clear that, even in an acoustically well-designed classroom, the teacher must speak over a noise level that is in the range of 45 to 55 dBA -- often more. How, then, is a teacher to reach, with clearly intelligible speech, the farthest students? It would require her to scream at a level of 75 to 80 dBA, and she could not sustain that through a teaching hour, much less a day! And children hate to be screamed at!

Sound Enhancement: An Educational Technology

There is now an established technology for distributing the teacher’s voice throughout the classroom at a normal 65 dBA speaking level. Traditionally called “sound-field amplification,” it is more appropriately called “sound distribution” or “sound enhancement.”

A sound enhancement system is not much different from a simple wireless public address system, but it is designed specifically for classrooms to assure that the teacher’s voice -- including the all-important, weak, high-frequency consonants -- reaches every student in the room – at a normal speaking voice level, not shouting.

Using a wireless microphone with an infrared signal, her voice is transmitted to a receiver which then distributes it electronically to two or four ceiling-mounted speakers -- each delivering the teacher’s voice at her normal conversational level. She can move about freely, even turn her back on parts of the class, knowing that her voice is being heard.

With a sound-enhancement system in place, the teacher's conversational voice at 60 to 65 dBA is available to every student, exceeding the 15 dB sound level to background noise ratio (SNR) required for adequate speech intelligibility, but without increasing the loudness of her voice.

By positively demonstrating their effectiveness, sound-enhancement systems have gained a wide and growing acceptance in U.S. schools. And while these systems are not usually equated with the term "classroom technology," they nevertheless are, and what better technology than one that ensures that students hear the lesson?

.

The ASA, however, has taken a different position. Its representatives assert that this amounts to "amplification" and is not necessary if a 35 dBA background noise level is obtained in an empty classroom. And they have produced a public-policy paper describing their reasons for opposing such "amplification" – including "blasting of sound" throughout the room and into adjoining rooms. This is just not true.

The ASA perception of classroom amplification – LOUD!

The ASA acousticians have not kept current with the greatly improved technology in these systems in the past 10 years. And they have been unwilling to accept the findings that classroom noise is generated by the students, not by building systems. Their position paper is based on misperceptions of the current technology and misunderstanding of the actual dynamics of an operating class.

Sound enhancement systems are not loud. Teachers' voices do not have to be raised to be heard. Students also use the microphone to read or recite. When students are working in small groups, they are close together and the sound enhancement system is not necessary.

Students hear the teacher clearly. The class hears a student recite clearly – and the student is empowered by the microphone.

No one has to raise her voice. Order is better – those without the mike don't talk. And since no one has to speak "loud," overall sound levels are lower.

Sound-enhanced classroom:

The reality is that a classroom with a sound-enhancement system is a QUIET classroom.

Benefits of Sound Enhancement

Teachers have reported that with sound enhancement systems, they need to use less energy projecting their voices, suffer less vocal abuse, and are less tired by the end of the school day.

Teachers also report that their efficiency as teachers is increased, requiring fewer repetitions and allowing more actual teaching time.

For students, research has reported significant benefits in the areas of literacy and academic achievement, speech recognition in quiet and noise, and on-task behavior related to attentional skills and learning behaviors.

Students, teachers, parents, and school administrators have indicated positive approval for the use of sound field technology in classrooms (Crandell, Smaldino, & Flexer, 2005).

As more and more schools incorporate principles of inclusion, placing children in mainstream classrooms who might otherwise have been separately placed, sound field distribution systems can enhance the classroom learning environment for the benefit of all children.

Educational audiologists, speech-hearing therapists, teachers, parents and school leaders have expressed positive approval for the use of sound enhancement systems in classrooms. They are beginning to recognize that the ASA requirement for empty-classroom background noise and its opposition to "amplification" do NOT assure adequate hearing in the classroom and that teachers' voices and nerves are suffering in attempting to be heard.

These involved educators are now enthusiastically endorsing sound-enhancement systems both for better learning and for teacher retention.

To see updates on this whitepaper, please follow the link below:
http://www.armstrong.com/commceilingsna/article21193.html

REFERENCES:

ACOUSTIC DESIGN GUIDELINES AND TEACHER STRATEGIES FOR OPTIMISING LEARNING CONDITIONS IN CLASSROOMS FOR HEARING AND HEARING-IMPAIRED CHILDREN

Bridget Shield, School of Engineering, South Bank University, London, and Julie Dockrell, Institute of Education, London University, Equal Research Network Workshop, March 21-22, 2002, University of Reading, Whiteknights Campus.

FIELD REPORT: BACKGROUND SOUND LEVELS IN CLASSROOM

San Pascual Elementary School, Los Angeles Unified School District, April 27, 2004.

FIELD REPORT: CONTINUOUS SOUND-LEVEL RECORDING IN CLASSROOM,

Gratts Elementary School, Los Angeles Unified School District, May 11-13, 2004.

THE ACOUSTIC ERGONOMICS OF SCHOOL

Report of the Research on the Sources and Impacts of Noise in the Classroom Learning and Teaching Environment, conducted for the German Federal Institute for Occupational Safety and Health at the Institute of Interdisciplinary School Research (ISF), University of Bremen, Germany, by Dr.Markus Oberdörster and Dr.Gerhardt Tiesler, Publication Series Fb 1071, Federal Institute for Occupational Safety and Health, Germany, 2006.

SOUND-FIELD AMPLIFICATION: APPLICATIONS TO SPEECH PERCEPTION AND CLASSROOM ACOUSTICS

C.C. Crandell, J.J. Smaldino, C. Flexer, 2nd Edition, 2005, New York, N.Y., Thompson Delmar Learning.