Classroom Acoustics II: Acoustical Conditions in Elementary School Classrooms

Martin A. Gold, Hee Won Lee, Gary W. Siebein, Mitchell Lehde,
John Ashby, Mary Jo Hasell, Philip Abbott, and Carl C. Crandell

Architecture Technology Research Center, University of Florida, P.O. Box 115702, Gainesville, FL 32611-5702

Abstract: Acoustical measurements of speech transmission index, reverberation time, early reverberation time, early to late energy ratios, loudness (or relative strength), articulation index, background noise levels and signal to noise ratios were made in a number of elementary and middle school classrooms in one school district to see how many rooms actually had acceptable acoustical conditions. The source and receiver locations for the acoustical measurements were determined through the participatory action research described in Classroom Acoustics I. Measurements were made using a TEF analyzer with custom software to compute additional acoustical measurements. Both omni-directional and directional loudspeakers were used for the source signals. The STI values were always greater than 0.75 for the conditions under which the teachers actually taught. Speaker to listener distances of 4 meters or less were observed for many classroom activities. Likewise the teachers employed many creative ways to control the behavior of the students to reduce background noise levels while they actually spoke.

THE CLASSROOMS

The classrooms were relatively similar to each other in room volume and interior finishes. The floors were carpeted. The ceilings were acoustical ceiling tile with an NRC estimated to be 0.50-0.60. The walls were painted masonry. One wall was typically an exterior wall that had windows from desk height to the ceiling. Half of the classrooms had central air-conditioning systems. The other half had through-the-wall heat pump units with no ductwork attached. The rooms with central air-conditioning systems had background noise levels between NC 30 and NC 40 with the air-conditioning system operating. The rooms with through the wall air-conditioning units had background noise levels of NC 40-NC 55 when the units were operating and NC 30-NC 35 when they were not operating. One of the rooms was a portable classroom. All of the rooms had some partial height furniture such as book shelves to divide the room into smaller sections. They also had tables, chairs and a teacher's desk. The ceilings were flat with a height of between 3 m (10 ft) and 4 m (12 ft). The length and width of the rooms were slightly less than 10 m. (30 ft).

ROOM ACOUSTICS MEASUREMENTS

Acoustical measurements were made at multiple source and receiver locations in eight classrooms in four schools. Measurements were made of sound pressure levels of speech and background noises during actual classroom sessions as well as in unoccupied classrooms. The source and receiver locations for the acoustical measurements were based on the observations of actual classroom use described in Classroom Acoustics I above.

Reverberation times (unoccupied) varied in the rooms from 0.35 s to 0.70 s. at mid frequencies. The reverberation times did not vary with location in the rooms. The early decay times were shorter than the reverberation times at locations close to the source. Values of the relative strength (G) were highest on axis and close to the sound source. As one moved off-axis and/or farther away from the sound source, G values decreased. The decrease of 6-9 dB at the rear and sides of the rooms represents significant differences in perceived loudness of sounds. The STI values also decreased towards the sides and rear of the rooms. STI values also decreased when the air-conditioning system came on. However, the teachers only taught in situations representative of receivers M4 and M3 in the rooms observed with corresponding STI values of 0.86 or greater.

Relative strength values were also measured for a source simulating a teacher sitting across a table reading to a small group of children while others were working at tables located around the room. The STI at the receiver location across the table was 0.92/0.85. The results of these tests are summarized in table 2 below. This implies that while children at the table with the teacher can hear her/him quite well with an absolute loudness of 60-65 dBA, the sound levels at other tables around the room are significantly reduced.

RESULTS

The results of this study indicate that teaching methods such as minimizing teacher to student distances, repetition and average classroom design can result in reasonable acoustical environments for learning. Teachers adapted to the excessive noise from the through-the-wall air-conditioning units very well. Several teachers would turn the units off

when they wanted to talk to the students or when tasks requiring concentration were undertaken. Other teachers would run the units while the students were at computer, music and other classes out of the room and just leave them turned off during normal use of the classrooms.

The portable classrooms presented difficult acoustical challenges. The reverberation times and other acoustical measures made in the rooms had lower values in the low frequencies and higher values in the higher frequencies than the site-built classrooms as a result of the panel construction. This resulted in a harsh high frequency brilliance of sounds in the rooms. The noise from students within the portable classrooms including moving chairs in and out, shifting in their seats, etc. all created this harsh sound as did creaking floors from shifting in chairs, impacts on the floors, etc. that were noticeable to the students. In many cases these interruptions stimulated behavioral changes. Other students became restless and began moving around. Soon the general noise level would increase in the room.

TABLE 1. Relative loudness and STI values found in classrooms at different source and receiver locations. These tests simulated a teacher talking at the front of a room to children seated at desks located throughout the room.

Source Location	Receiver location	Relative loudness of sound (dB)	STI value (AC on/AC off)	Background Noise Level (dBA) AC on/AC off
S1 front, center of room 1 m. from board	M4 front, center of room 2 m. from source	0 dB	0.90/0.82	52/41 dBA
S1 front, center of room 1 m. from board	M3 rear, center of room 4 m. from source	-4 dB	0.86/0.64	54/41 dBA
S1 front, center of room 1 m. from board	M2 rear, side of room 6 m. from source	-6 dB	0.79/0.51	53/41 dBA
S1 front, center of room 1 m. from board	M1 side, front of room 4 m. from source	-9 dB	0.69/0.45	52/41 dBA

TABLE 2. Relative loudness values found in classrooms at different source and receiver locations. These tests simulated a teacher talking across a table to a small group of children while other children worked at tables located around the room.

Source Location	Receiver location	Relative loudness of sound (dB)
S2 side, front of room, at table	M1, side, front of room, 1.8 m. from source	0 dB
S2 , side, front of room, at table	M2, rear, side of room, 4 m. from source	-13 dB
S2 , side, front of room, at table	M5, opposite side of room, 6 m. from source	-16 dB
S2, side, front of room, at table	M6, opposite side of room, 8 m. from source	-14 dB

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