OPEN SYSTEMS

Acoustics and Learning

Here's a true story. Julie attends school in New York City. Math isn't her strongest subject, but she understood her teacher last year and passed with a B+ in his class. She will move on to the eighth grade next year. Her classroom was built with acoustical ceiling tiles and carpet. Her classroom walls were built with dense materials, so she wasn't distracted by noise in the adjacent classroom.

Tom also attends school in New York City. Math used to be one of his strongest subjects, but Tom didn't pass last year because he couldn't understand his teacher. Sound from the nearby airport and a noisy air conditioning unit in the corner of the room masked some of his teacher's voice. Tom may have passed if he could have heard his teacher a little better.[1]

Much of learning depends on hearing the teacher. Hearing well requires an environment free of acoustical problems.

The importance of classroom acoustics has gained increasing recognition in recent years, and the research is convincing. The Acoustic Society of America (ASA) reports that students in many classrooms can understand only 75 percent of what their teachers are saying.[2] This problem is especially acute among students with learning disabilities who can't fill in the blanks. Additional studies consistently link higher student achievement to quieter classrooms.[3]

So it's hard to imagine that we continue to build schools with poor acoustics. But we do.[4]

To address this concern, the American National Standards Institute (ANSI) last year approved performance standards and best practices for improving classroom acoustics. Many state governments and school districts have adopted similar standards with the same goal in mind: to improve classroom acoustics and learning by *reducing outside noise* and *optimizing sound within* the learning space.

These standards identify performance criteria to achieve good classroom acoustics, as well as some guidelines to meet those criteria. So what are they?

Reduce Outside Noise

Background noise—mechanical equipment, noise from adjacent classrooms and noise from outside the classroom—is disruptive to learning.[5]

Mechanical Noise

The HVAC system is the biggest culprit. It doesn't have to be. Consider a few guidelines.

[1] In a 1999 Study, Evans and Maxwell compared the reading scores of two schools in New York, one of which was in the flight path of an airport. The students exposed to the air-traffic noise scored as much as twenty percent lower on tests than the other school.

[2] ASA (Acoustic Society of America). 2000. Classroom Acoustics. Retrieved 7/13/03 from http://asa.aip.org/classroom/booklet.html

[3] ANSI (American National Standards Institute). 2002. Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools. ANSI S12.60-2002. pp. 10-11

[4] A third of the schools cited in a 1995 General Accounting Office study reported that acoustics were the most serious environmental concern.

[5] ANSI recommends a maximum background noise of 35 decibels for classrooms

- **Locate rooftop mechanical equipment and air handlers away from critical listening spaces.** Position units over noisy areas such as hallways, gymnasiums and auditoriums.

- **Avoid running ductwork through adjacent classrooms.** Position mechanical equipment over hallways and run ductwork to nearby classrooms (Figure 1).

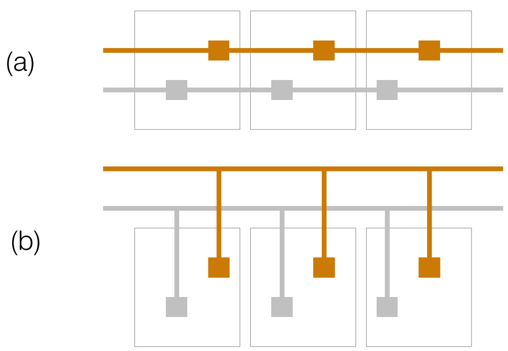

Figure 1. Poor (a) and good (b) ductwork design

- **Avoid window or room units in classrooms.** These systems are notoriously loud and difficult to treat with sound absorbing materials. A teacher shouldn't have to compete with a fan coil unit for his or her students' attention.

Noise from Next Door

When schools were built with heavy brick and concrete block, noise traveling between classrooms wasn't much of a problem. In recent years, however, bad design and cheap construction have led to the use of thinner, more lightweight materials that promote poor acoustics.

There are a few steps that will reduce noise between classrooms:

- **Build dense interior walls.** Many walls today are constructed of two layers of 5/8 inch gypsum board around an airspace with metal studs. This arrangement will not meet the ANSI standard.[6] Add extra layers of gypsum and some fiberglass insulation (Figure 2). This will improve the sound isolation and meet the standard.

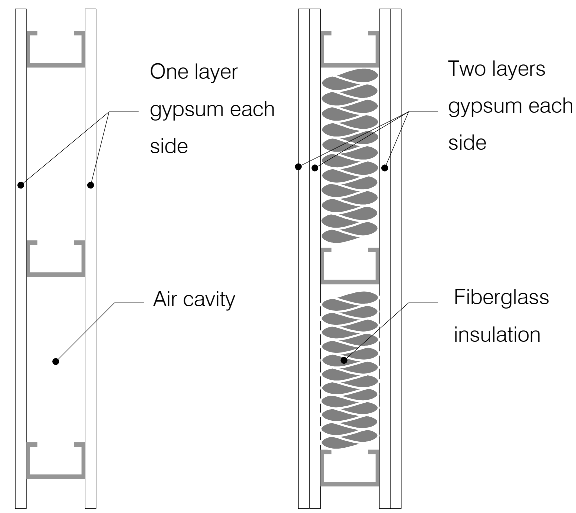

Figure 2. Methods to improve STC ratings for interior walls

- **Seal gaps in the walls, floors and ceilings with acoustical sealant.**

- **Avoid doors that connect adjacent rooms.** Add weather stripping to those connecting doors that are necessary. Also avoid placing doors directly across the hall from each other that will allow noise to travel between classrooms.

- **Expensive, sound absorbing walls may be avoided with preventative design.** Early in the design process, identify noisy areas (mechanical rooms, gyms, cafeterias and music rooms) and use buffer areas (hallways, storage rooms and restrooms) to separate these spaces from critical learning spaces (classrooms, libraries, special education rooms).

- **Extend partition walls to the structural ceiling.** Otherwise, sound can travel over the partition into the next room (Figure 3).

[6] ANSI recommends a minimum STC of 50 for interior walls between classrooms

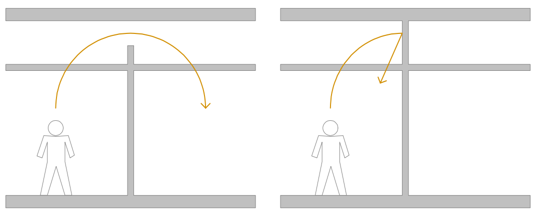

Figure 3. Sound transmission though the ceiling plenum

Outdoor Noise

Noise from traffic, planes and people outside should be kept out of the classroom.

- Windows must be well sealed. Consider using noise-reducing window systems, such as double-pane glass. (In addition to acoustic performance, double-pane glass will improve the thermal insulation and decrease energy costs.)

- Identify sources that disrupt learning and try to locate classrooms away from those sources. It may be impossible to eliminate all noise sources, but thinking about it early may produce the right result.

Optimize Sound Within

In addition to keeping noise out, it's critical that sound characteristics of the classroom itself are optimized.

Reverberation

Reverberation is the time it takes for sound to disappear. In most cases – especially in classrooms –shorter reverberation is good. Long reverberation is great for an organ recital, but not for speech. It creates an echo and blurs spoken words. However, very short reverberation times make it difficult for students in the back of a room to hear. The key is to strike a balance. Table 1 gives some acceptable reverberation ranges for different learning spaces.[7]

[7] Acoustical Society of America, "Classroom Acoustics: A Resource for Creating Learning Environments with Desirable Listening Conditions," 2000

Space Type	Min	Max
Classrooms	0.4	0.6
Cafeterias	0.8	1.2
Gymnasiums	1.2	1.6
Auditoriums	1	1.6
Music Rooms	0.6	1.2

Table 1. Acceptable reverberation ranges

Source: Acoustic Society of America

Calculating the reverberation is relatively simple. Just take the volume of the classroom, multiply it times a coefficient, and divide by the sound absorption quality of materials in the classroom. Based on this equation, there are two variables that can be adjusted to control reverberation – *volume* of the class and the *materials* used.

- The bigger the room, the longer the reverberation. Invariably, function will dictate size, but there are still a few rules of thumb—all other things being equal.

- Avoid disproportionate spaces. A length to width ratio within 3:2 is good.

- Tall ceiling heights increase reverberation. Ten feet is good for a typical classroom.

- In addition to volume, reverberation is also affected by the materials used in a classroom. Fuzzy materials, such as carpet and lay-in ceiling tile, are the most common method to reduce reverberation.[8]

- Acoustical ceiling tile will sometimes be enough to achieve acceptable reverberation. The tile should have a Noise Reduction Coefficient (NRC) of at least 0.75. The NRC indicates the average percentage of sound that a ceiling absorbs. For example, an NRC of 0.75 indicates that the ceiling absorbs 75 percent of the sound it receives. The NRC of a few common interior materials is given in Table 2.

[8] Noise vibrates the fibers in fuzzy materials and turns sound energy into mechanical energy that is then dissipated as heat. A classroom full of students with long hair wearing wool shirts will actually affect reverberation time.

- **Typically, carpeting alone will not provide enough sound absorption for classrooms.** However, carpeting is effective to reduce noise from moving furniture and foot impact, and to isolate noise from the room below.[9]

Material	NRC
Acoustical ceiling tile	0.75
Carpet on underlay	0.7
Medium Fabric	0.57
Gypsum	0.04
Wood floor	0.03
Brick wall (painted)	0.02
Terrazzo floor	0.02
Glass	0.02
Marble tile	0.01

Table 2. Sound absorption of some common materials

It is often necessary to reflect a teacher's voice to the back of a room. This can be accomplished by creating a partially absorptive and partially reflective environment (Figure 4). One approach is to put sound absorbing acoustical tiles around the perimeter of the ceiling grid and gypsum board panels in the middle. Additional sound can be reflected by shaping the ceiling surface over the teacher's location (if it is certain where that will be) and around the perimeter if necessary. Placing absorptive materials on the walls simultaneously will help reduce the reverberation and decrease echoes.

It will also minimize the possibility of standing waves. Standing waves are caused by sound that hits a wall and bounces back to an opposite wall. If the sound frequency is precisely divisible into the distance between the walls, the sound at that frequency will be substantially reinforced. Hence, parallel walls in music rooms should be covered with acoustical material or not be parallel.

[9] ANSI Standard, pg 22

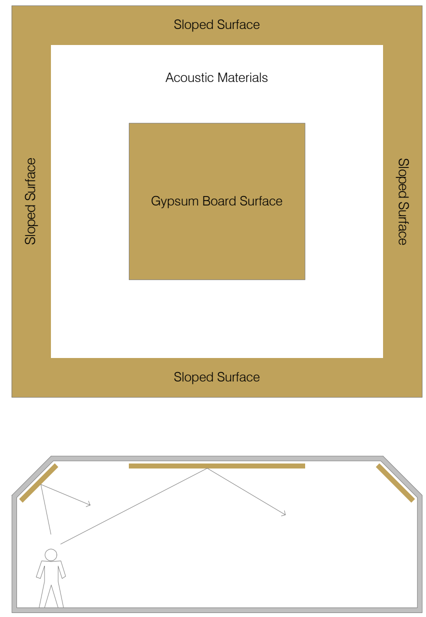

Figure 4. Alternative acoustical treatments of the ceiling

Source: Collaborative for Higher Performing Facilities (2002)

New Technology

We have used classroom sound reinforcement (or voice amplification) systems, and teachers love it. It's an inexpensive solution[10] for classrooms with poor signal-to-noise ratios.[11] Even where there is no extraneous noise, the teachers like speaking to the entire class in a normal voice.

A typical system consists of a lightweight wireless microphone worn by a teacher combined with several low volume speakers at several points in the classroom ceiling. The teacher's voice is amplified, increasing speech intelligibility for the students and decreasing vocal strain for the teacher. In addition, the teacher can move freely and maintain a constant voice level.

Until recently, voice amplification systems have typically been used in existing schools with high levels of

[10] FM and infrared wireless systems are available today with costs ranging from $500 - $2,000 per classroom.

[11] The signal-to-noise is a comparison of a teacher's voice versus the background noise in a room

background noise. But because of the flexibility and improvement, more owners are implementing the technology in new schools.

Typically, there is no sense of electronic amplification. An interesting acoustical phenomenon is that sound produced from natural sources (voice, musical instruments, etc.) will sound natural if the natural signal is audible as part of the amplified signal.

A typical classroom sound reinforcement system

Conclusion

An effective learning environment depends on good acoustics. There are many ways to achieve it with little or no extra expenditure. But with commitment and good design, learning can be materially enhanced.

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