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BY EWART A. WETHERILL

Classrooms may be noisy... simply because of the way they are constructed and finished. It is a blocking fault, for the need to hear well is basic in education.

McQuade, Schoolhouse, 1958

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While the impetus for the standard began initially as an effort to improve schools for children with impaired hearing or other learning disabilities, children with normal hearing will also benefit greatly from these standards. The good news for architects and builders is that compliance with the acoustical standards need not be costly or difficult if they are incorporated early into the planning and design process, although remodeling existing facilities could be expensive depending on the actual situation. The requirements for good hearing were first presented formally to the American Institute of Architects in 1898 and have been successfully applied to many schools. However, in the absence of enforceable standards far too many schools have been built with little or no concern for good hearing. Since acoustical problems are created by the design they can just as easily be avoided by the design.

The Noise Pollution Clearinghouse is the largest national non-profit organization working to reduce noise pollution. It's website, www.nonoise.org is the world's largest online noise library, with 2,100 users each day and more than a gigabyte of data concerning noise pollution. For more information about noise and schools, call NPC toll free at 1-1888-200-8332 and ask for a copy of the Fall 2003 newsletter and a list of further reading resources. The Quiet Zone, the newsletter of the Noise Pollution Clearinghouse. It appeared in the Fall 2002 issue.

The Noise Pollution Clearinghouse is a public enterprise, is conducted in more than 80,000 schools as easily be avoided by the design.
listener hearing words in the context of a sentence can fill in words or syllables that are not heard clearly, depending on the size of the listener's vocabulary. Since children have smaller vocabularies, they are less able to fill in the words not heard clearly. Similarly, someone using English as a second language or someone who suffers from an attention deficit disorder are at a significant disadvantage in a noisy classroom. In addition, many children with usually normal hearing have temporary hearing losses from illness. 

Compounding the learning disadvantages that confront children in noisy classrooms or with impaired hearing are the constant discouragement and frustration that can inhibit the motivation of even the most talented to learn and to excel.

The importance of clearly hearing the teacher seems self-evident, but this has not been a design criteria of many schools in the past.

**Requirements for Good Hearing**

Two basic criteria must be satisfied to meet the requirements for good hearing:

1. A quiet background (e.g., noise from intruding traffic, adjacent classes, ventilation systems, etc.)
2. Control of reverberation and self-noise

**Speech to Noise Ratio**

Speech in the classroom must be heard over the prevailing background noise level, be it intruding traffic, adjacent classes, or a noisy ventilation system. A convenient and easily measured descriptor is the speech to noise ratio (S/N). There is general agreement that desired S/N ratios for speech recognition are:

- Normal-hearing: Adults: at least 6 decibels
  - Children: greater than for adults, at least 10 decibels
- Hard-of-hearing listeners: Adults: at least 15 decibels
  - Children: greater than for adults

By contrast, a survey of actual classroom conditions taken between 1965 and 1968 indicated a speech to noise ratio range from +5 decibels to -7 decibels. This information alone adds support to the growing concern both for children's understanding and for teachers' voice strain.

Reverberation (commonly known as an echo) is defined as the persistence of sound in a room after the source has stopped. In a reverberant space, successive syllables blend into a continuous sound, through which it is necessary to distinguish the orderly progression of speech. The level at which this sound persists is determined by the size of the space, the speech level and the interior finish materials.

Reverberation time (the time it takes for a sound to die off) is measured in seconds, with a low value—around 0.5 seconds or less—being optimum for a classroom seating about 30 children. Reverberation can be controlled by the use of readily-available sound-absorbing wall and ceiling materials that comply with building code requirements.

**Effects of Noise and Reverberation on Speech Recognition**

- Mean speech-recognition scores (the percent of words correctly recognized) of adults with normal hearing for various S/N ratios clearly demonstrate the connection between good acoustics and effective hearing.
- Normal-hearing: Adults: at least 6 decibels
  - Children: greater than for adults, at least 10 decibels
  - Hard-of-hearing listeners: Adults: at least 15 decibels
  - Children: greater than for adults

The combined effects of poor Speech to Noise and long reverberation time for children, which is the actual situation encountered daily in many of the nation's schools, are predictably a substantial handicap to entire classes. The following scores are for monosyllabic words.

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Normal Hearing %</th>
<th>Hearing Impaired %</th>
</tr>
</thead>
<tbody>
<tr>
<td>+12 decibels</td>
<td>89.2%</td>
<td>70.0%</td>
</tr>
<tr>
<td>0 decibels</td>
<td>60.2%</td>
<td>39.0%</td>
</tr>
<tr>
<td>FOR REVERBERATION TIMES OF 1.2 SECONDS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+12 decibels</td>
<td>68.8%</td>
<td>41.2%</td>
</tr>
<tr>
<td>0 decibels</td>
<td>29.7%</td>
<td>11.2%</td>
</tr>
</tbody>
</table>

Speech in a Non-Reverberant Space

Reverberation can be controlled by the use of readily-available sound-absorbing wall and ceiling materials that comply with building code requirements.

**Effect on Teachers**

In addition to children's hearing concerns, the effect of trying to compete with an acoustically-difficult environment creates a problem of severe strain on the vocal chords for many teachers. While not as well-known or studied as the listener's ability to understand, voice strain is belatedly being recognized as a serious and potentially incapacitating problem for teachers. However, effective acoustical treatment of a classroom can create significant benefits here also.

**Examples of Effective Classroom Design**

Designers and builders can improve hearing conditions in schools by incorporating the basic principles of acoustics into classroom design. For every new and remodeled school, the control of unwanted sounds and enhancement of wanted sounds, without the complications inherent in general amplification, should be placed high on the list of design goals. For new classrooms accommodating from 30 to 40 children these requirements should not add anything to the cost of either design or construction. However, correction of acoustical deficiencies in existing facilities could be costly, depending on the particular situation.
listener hearing words in the context of a sentence can fill in words or syllables that are not heard clearly, depending on the size of the listener's vocabulary. Since children have smaller vocabularies, they are less able to fill in the words not heard clearly. Similarly, someone using English as a second language or someone who suffers from an attention deficit disorder are at a significant disadvantage in a noisy classroom. In addition, many children with usually normal hearing have temporary hearing losses from illness. Otitis Media, a bacterial infection of the middle ear that is the most frequently-occurring childhood medical complaint, has more than doubled in the last decade.

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<table>
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<tr>
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<th>Normal Hearing</th>
<th>Hearing Impaired</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 decibels</td>
<td>94.5%</td>
<td>87.5%</td>
</tr>
<tr>
<td>+12 decibels</td>
<td>95.5%</td>
<td>89.2%</td>
</tr>
<tr>
<td>+6 decibels</td>
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EFFECTS OF NOISE AND REVERBERATION ON SPEECH RECOGNITION

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Test Condition | Normal Hearing | Hearing Impaired |
---------------|----------------|------------------|
For Reverberation Times of 0.0 Seconds: |                  |                  |
+12 decibels   | 89.2%          | 70.0%            |
0 decibels     | 60.2%          | 39.0%            |
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The following conclusions can be drawn from these test results and from corroborating evidence compiled from other test situations.

1. Understanding of children with normal hearing can be seriously affected by a combination of excessive background noise and reverberation.
2. Hearing impaired children are always at a disadvantage compared to those with normal hearing but the difference can be minimized by acoustical controls.
3. Comprehension levels for multisyllabic and unfamiliar words can be expected to be worse than indicated by monosyllabic testing.
4. Decrease in intelligibility with distance from the teacher can be minimized by acoustical treatment and shaping of the space.

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EXISTING CONDITIONS IN U.S. SCHOOLS

Elementary and secondary education, the nation's largest public enterprise, is conducted in more than 80,000 schools in about 15,000 districts. America's public schools serve more than 42 million students.

In February 1995, the U.S. Government Accounting Office (GAO) presented a report to the U.S. Senate on the results of a survey of school officials across the country on the physical condition of their facilities. The report comprised hard facts concluding that more than $100 billion would be needed to restore all of the schools to good condition. The most frequently mentioned of all the "unsatisfactory environmental conditions" was "acoustics for noise control."

One outstanding example of acoustical inadequacy can be found in the standards set by the Los Angeles Unified School District, one of the largest in the country. These allow the use of classroom ventilation/air conditioning units that are up to 20 decibels noisier than would be permitted by Swedish standards. The inevitable conclusion is that school children cannot hear much of what is said, while teachers must shout to be heard at all. A second example that should be familiar to many was the disastrous trend in the late 1960s to open-plan schools. These created a situation in which some school children could hear the teacher of an adjacent class more clearly than their own teacher.

Thus, a combination of outdated facilities and unfortunate design or construction decisions leave us with an inheritance that will be a burden for decades to come. This legacy of past policies will consume a very significant part of the limited funds that many communities seem currently willing to allot to school construction or renovation; so skillful planning and site selection will be essential to attain the new goals.

CHILDREN AT RISK

In December 1997, representatives of eleven national groups joined the Acoustical Society of America in a workshop on Eliminating Acoustical Barriers to Learning in Classrooms. From this workshop has developed a coalition that worked actively to further improved hearing conditions in schools. Leaders in the field of audiology and a wide range of disciplines related to design and construction of educational facilities presented the results of surveys and research on the prevalence of hearing disorders and substandard facilities, and their effects on hearing. The truly alarming statistics clearly show the disadvantage resulting from poor hearing conditions for both normal and hearing-impaired school children.

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