Teaching and Learning in 'Acoustical Darkness'

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When we dare not teach in a room without light, why teach in acoustical darkness? Several generations of students and teachers have battled the inherent problems caused by noise and poor room acoustics in critical listening spaces. 100 years and more of research on classroom acoustics have passed by and yet we still encounter communication and listening problems in classrooms today. This has a bearing on the learning outcomes, performance and productivity of both students and teachers alike. Without sensitively understanding the aural comfort needs of the classroom users, many classrooms today are acoustical treated and overdesigned at very high costs. These unsustainable practices can be avoided by careful planning and consideration, early on during the design phase of the educational building.

Classrooms are complex learning environments with a myriad of factors influencing speech perception and intelligibility. The accurate transmission of information in the classroom is imperative for learning and academic success. However, there are many factors in classrooms which hinder effective communication. In tropical climates like India, classrooms are typically naturally ventilated with large open windows and are also fitted with noisy ceiling fans to keep the occupants comfortable. The speaker's speech level although audible in most cases across the classroom, however may not be intelligible. Distortions in speech are caused by the persistence of reflections in the room, a phenomenon known as reverberation. Hard surfaces typically encountered in the classroom such as desks, benches, blackboard, glass windows, concrete walls are all responsible for

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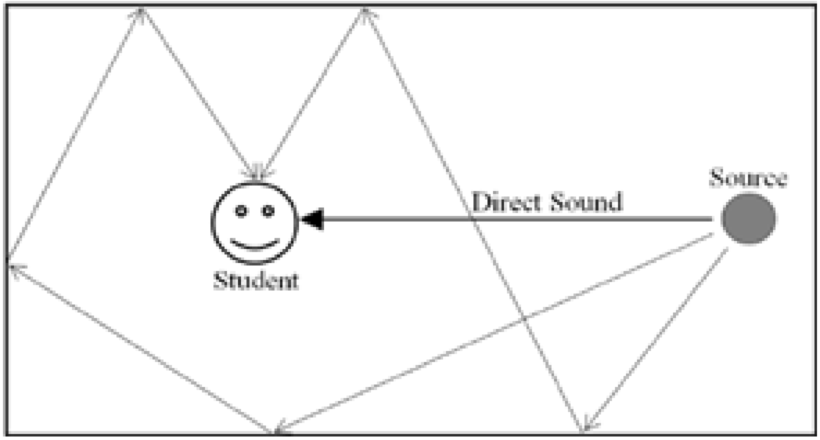
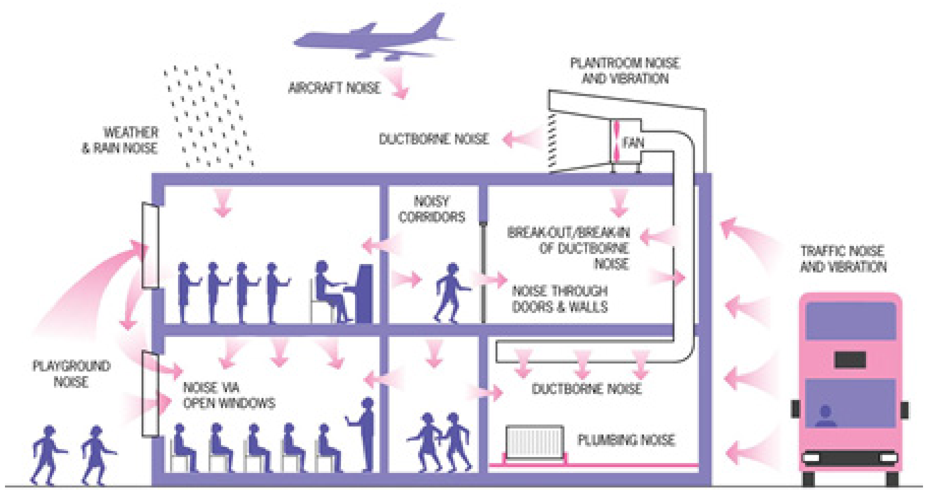


reflecting off the incident sound energy back into the room. These reflections arrive at the listener's ears from different directions at time intervals that are milliseconds apart. This creates a smearing of the sound and makes it difficult for the brain to distinguish the primary speech information and disseminate it from the reverberant portion. The problem is exacerbated in the presence of high ambient noise levels. Ambient classroom noise levels degrade the speech quality by reducing the signal to noise ratios at different student locations in the classroom. The farther away you sit from the speaker, the more likely you are to experience speech perception difficulties. Apart from these internal factors, open windows also contribute to their share of degrading the acoustical environment in classrooms by bringing in a plethora of noises from the outside world, such as, vehicles honking, construction noise, people talking outside etc. Different noises have different effects on speech perception and intelligibility depending on the frequency content present in these sources.



Since majority of learning in classrooms occurs through verbal communication of ideas and information, words or sentences missed during a distractive noise event can never be brought back into a student's life again and that is information lost forever to him. Many students miss up to 1 in 4 words spoken by their teacher due to poor intelligibility as a result of degraded listening conditions in classrooms. Reducing ambient noise levels in the classroom also makes it easier to teach and significantly reduces vocal fatigue and the stress imposed on the teacher. Thus, poor acoustical conditions in classrooms hinder the teaching – learning process considerably.

In an attempt to characterize the acoustical quality of naturally ventilated classrooms in India, the author got involved in conducting experiments, as a part of the research program at IIT Madras, involving measurements of reverberation time and ambient noise levels in selected classrooms of varying geometry and characteristics under both unoccupied and occupied conditions. Typical values recorded for reverberation and background noise are higher than most values found in literature. The A-weighted background noise levels observed vary from 35 dBA to 63 dBA in university classrooms and 57 dBA to 63 dBA in school classrooms. The signal to noise ratios range between +34 dB to +7 dB in university classrooms and +12 dB to +7 dB in school classrooms. The reverberation time measured in the 1 KHz band range from 0.37 to 2 seconds in university classrooms and 0.65 to 1.44 seconds in school classrooms. The ANSI S12.6 – 2002 standard recommends unoccupied reverberation times in the range of 0.6 – 0.7 seconds and unoccupied ambient levels of not more than 35 dB L_{Aeq}. The NBC 2016 has recommended unoccupied reverberation times at 500 Hz to not exceed 1.1 seconds. The measured reverberation times do not comply with the ANSI standard and the NBC 2016.

Occupant absorption plays a significant role in bringing down the reverberation times to acceptable or near acceptable values especially at the high frequency bands beyond 1 KHz. This becomes favorable to speech communication as majority of the consonants lie in the frequency range of 1000 – 4000 Hz and consonants contribute to 75% of the information that is delivered in speech. Measurements of reverberation times in occupied conditions indicate that reverberation times decrease with increasing occupancy and it is seen that average mid frequency reverberation times are brought down by 0.4 seconds. However, this reduced reverberation time along with the ambient noise levels needs to be brought down further for comfortable speech communication in classrooms.

Speech intelligibility is the single most important measure of communication success in classroom environments. It is the degree of match between the intention of the speaker and the understanding of the listener. There are many methods employed to measure intelligibility. The most straightforward way is to make the listener repeat the word, phrase or sentence spoken by the speaker. The number of correct words is scored and speech intelligibility score is indicated as a percentage. However, these subjective evaluations are time consuming and need considerable human effort. An objective evaluation of speech intelligibility is commonly used instead and is known as the STI (Speech transmission index). The speech transmission index is a single number rating of the effectiveness of the communication channel and ranges between 0 and 1, where 0 corresponds to worst intelligibility and 1 corresponds to best intelligibility.

STI was measured as part of the experiments in unoccupied classrooms. A calibrated signal generator featuring human head-like dimensions was used to generate the signal instead of natural speech. The generated signal has an output level of 70 dBA at 1 meter and consists of frequencies similar to that of the human speech spectrum. At the receiver locations i.e. typical student seating positions, in the place of the receiver, the integrating sound level meter was positioned to capture the STI value. The STI value was found to decrease with increasing distance from the sound source. The STI values were higher when all ceiling fans in the classroom were turned off, as this increased the signal-to-noise ratio at the receiver locations. At the rear end of the classrooms STI was found to be very low indicating poor intelligibility at these locations of the classroom.

In order to enhance the intelligibility especially at the rear portions of the classrooms, speakers resort to the use of sound reinforcement systems. If not set up carefully, this more often only adds to the list of existing problems. The acoustical defects of the classroom also tend to get amplified in the process and make the situation worse. Occupants from adjacent rooms also get annoyed at the amplified noise levels received from the classroom. Moreover, different speakers have different speech characteristics and intelligibility varies across speakers significantly. Speech intelligibility tests are not robust enough to capture these subtle variations. For feeble speakers, voice training and other voice management techniques may help improve communication success. Such speakers would have to rely on acoustical surfaces in the classroom which can help enhance early reflections by channelizing them to different parts of the room having acoustical energy deficits. Reflectors positioned in classrooms at locations near the speaker can help improve the signal quality and reduce listening effort considerably. Thus strategic positioning of absorptive and reflective surfaces in the classroom can significantly improve the overall acoustical climate of the classroom and improve the speech intelligibility across the room.

The studies on classroom acoustics reveal that with a little thought to design and with minimal interventions, we can transform our classrooms and make teaching in 'acoustical darkness' a thing of the past and experience the joy of teaching and learning in 'acoustically bright' listening environments.