Sound reflections that support teaching and learning

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Summary
It’s important that class rooms provide good conditions for both listeners and speakers. To listen without effort is important for learning, and we know that a poor sound environment is a burden that impedes learning and have a negative effect on teachers voice health. Then we listen to a speaker in a room, we hear the speakers voice and the sound reflections from the surfaces in the room. The sound reflections have a great impact on both the speaker and the listeners. In most languages the information is carried out by the consonants, looking at the speech spectra we see that most vowels are low in frequency and high in strengths and most consonants are low in strength and higher in frequency. If the room reflections amplify the lower frequencies the “strong” vowels will be “stronger” and have a masking effect on the consonants. These rooms have low speech intelligibility. To create good speech intelligibility it is important that the surfaces in the room amplify the higher frequencies. A place that amplifies the higher frequencies is the Swedish forests. I have made several listening and speaking tests in different forests. Most people feel that it’s very easy to understand what the speaker says, good speech intelligibility, and it’s also very pleasant to speak in a forest, good speak comfort. I have measured the sound reflections in different forests. The results are interesting and I mean that “forest acoustics” should be the goal in terms of acoustic conditions in class rooms.

PACS no. 43.55
1. Introduction

Unnatural sound reflections deteriorate the speech intelligibility in many schools. For thousands of years we have lived outdoors and developed our senses in the outdoor environment. Hearing works very well outdoors where natural sounds from singing birds, gurgling sound from small streams, wind sound from the trees and human voices are common. The problem is that we spend the major part of our time indoors today, in an environment with very few natural sounds. This affects us a lot, especially pupils in the learning situation. Outdoors there are a lot of sound reflections from round tree trunks and hard stones with uneven surfaces, but in a forest there are no hard flat parallel surfaces. In the classrooms however, reflected sound from hard flat parallel surfaces are common. These reflections are unnatural and affect pupils and teachers a lot. The effect in a classroom is high sound levels and low speech intelligibility. In these rooms it’s hard for the students to understand what the teacher says and the teachers get voice problems due to big voice load. Being able to listen without effort is important for good learning and we know that poor room acoustics is a burden that impedes learning. Therefore it’s important that teaching spaces provide good speech intelligibility for listeners and good speech comfort for the speaker. A good example is forests where we can talk to each other over long distances without having to raise our voice. Some years ago when I was in a forest with my son I discovered that he could hear what I said at a distance of 20 meters, even though that I deliberately spoke with a low voice level.

The speech intelligibility in forests is extremely good. To investigate how good the speech intelligibility was I took a loudspeaker, an mp3 player and a sound level meter and went into a forest. I played an audio book from the mp3 player and controlled that the sound level was 60 dBA one meter in front of the loudspeaker.

This is a normal speech level then you talk to a person at a distance of 3-4 meters.
I sat myself on a chair and started to listened to the audio book, then I moved further and further away from the loud speaker. Even when I was 25 meters away from the loudspeaker I could easily hear and understand the content of the audio book. The background sound level in the forest was approximately 30 dBA. I invited 10 teachers to do the same listening test, and all of them were really surprised how good the speech intelligibility was in the forest. During this test they were listening to the sound from the loudspeaker, and the sound reflections from the forest. Since reflections are important for the speech intelligibility I decided to measure the reflections in the forest. I took an omnidirectional loudspeaker, a microphone and placed them in the forest. I sent out a sound (a sine sweep) and recorded the sound reflections from the forest, the so called impulse response. One way to describe the sound reflections is to measure the reverberation time. Then you measure how long it takes for the sound pressure level to drop 60 dB. According to the standard ISO 3382-2 [1] one can show the sound reflections.

Impulse response measurement in a forest.

When people talk we use vowels and consonants. If we look at the speech-banana we can see that vowels are high in strength (high dB level) and have therefore more energy than consonants.

Consonants and vowels in the speech banana.

Another important thing is that vowels are lower in frequency compared to most consonants. When we communicate it is important to hear the consonants because they carry the information in most languages. To create good speech intelligibility in a room it is important that the room-reflections support the consonants. Vowels, on the other hand, have more energy than the consonants and need therefore less support from the room. In Sweden we have a standard, SS 25268 [2] to classify the sound quality in school buildings. To control the room acoustics in classroom the standard put requirements on reverberation time according to ISO 3382-2 [1] I have measured the reverberation time in different forests in Sweden and I see an interesting pattern in the results.
In a forest there are a lot of sound reflections in the higher frequencies. And this is reflections from the tree trunks. When we measure the reverberation time in a forest there are some weak sound reflexes from the “floor” where we have grass, leaves and mosses. From the “ceiling” there are no reflexes because the sky don’t reflect sounds. But on the “walls” we have trees and they reflect the high frequencies. The explanation is that high frequency sounds have short wave lengths so they bounce in the tree trunks. Low frequency sounds have longer wave lengths so they go around the tree trunks and will not be reflected. This has a great impact on the speech intelligibility. Forests reflections support consonants but not vowels and this is the reason why the speech intelligibility is so good in the forest. One can say that the reflexes from the trees help people to articulate.

**Speech intelligibility and speak comfort**

Teachers use their voices a lot when they teach and many teachers in Sweden have problem with their voice health due to high vocal load. I asked the 10 teachers what the thought about the speak comfort in the forest. All of them said it was pleasant and they didn’t need to raise their voice to be heard.

**Acoustics in forests vs classroom**

One big different between forests and classrooms is the ventilation system. These systems create often disturbing sounds especially in the low frequencies. Ventilation sounds in classrooms is often a big problem that impedes learning. Another problem is that the sound reflections in classrooms support the vowels.

Reflected vowels mask the consonants and this is the reason why the speech intelligibility in many classrooms is low. Speech consists of vowels, O A E Y, voiced consonants, B M R V, and unvoiced consonants, S T F. Vowels and voiced consonants are produced with vibrating vocal cords. This vibration can be heard by the ear via the bones in our skeleton. But unvoiced consonants are produced without vibrating vocal cords, so the only possibility for the speaker to hear the unvoiced consonants is via the reflexes from the “room”. In a room with a lot of low frequency reflections the high frequency unvoiced consonants can’t be heard by the speaker and therefore the speak comfort feels low. When I compared forests with classrooms the results are interesting and I mean that forest-acoustics can be a source of inspiration for good classroom acoustics. Speaking and listening is important in the teaching-learning situation and since all teachers liked the sound environment in the forest both then they were asked about speak comfort and speech intelligibility I mean that classroom acoustics should resemble the forest as much as possible.

A teaching place with good acoustics [3].
2. Conclusions

When a teacher talk to the students in a classroom, the students hear the teachers voice and the sound reflections from the room. Unnatural sound reflections from hard, flat parallel surfaces deteriorate the working environment for students and teachers in many schools today. The effect is low speech intelligibility and bad speak comfort. It is important that the school buildings provide good speech intelligibility for the students and good speech comfort for the teachers. In a good classroom it’s easy for the students to listen to the speaker, and the speaker feel it’s pleasant to talk. In the forest the sound reflections from the tree trunks support the high frequency consonants and these reflections help the teachers to talk with a normal voice level. In the forest the students don’t need to put a lot of energy to understand what the teachers says. I mean that forest-acoustics can be a source of inspiration for good classroom acoustics. I also think that the sound environment in classroom acoustics should resemble the forest as much as possible.

References
