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Acoustics in the partial deaf student school music classrooms

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Abstract

Music schools need some special acoustical design for better education. If this is also for disabilities children, the effect is more important. This research is about musical education for partially hearing disabled children (PHSC). At this point architectural acoustic design acquires importance. This is not only in the shape of the room but also in using covering materials and other solutions.

The question is whether architectural acoustics solutions can effect the music education of PHSC or not. Here the first discussion is whether we need some additional components of good classroom acoustics for partially hearing disabled children in the American National Standards Institute, Standard S12.60 2002 for classroom acoustics, and the cost impact of the Standard. Childhood hearing loss is a wide speed problem with significant impact, an invisible condition resulting in communication problems that can ultimately interfere with learning and social development. Included are audios files that illustrate that even a mild hearing loss can have a significant impact on a child's ability to understand the teacher. Especially children with partial hearing loss need a more lively room to amplify the instrument sound for improved hearing capacity.

Key words: disability children, music education, architectural acoustic, classroom, deaf student.

1. Introduction

Subject has several aspect which including the reason of degree of partiality deafness children without any operation or recipient ion of cochlear implant, effect the deafness to the classical or musical education, effect the classroom noise level to the deafness and hearing impairment…. etc.

There are several types of reason for partial deafness for child. Classical segregation analysis was used to analyze the family data, and to estimate the proportions of sporadic, recessive and dominant causes of deafness in the families. These data were consistent with 37.2% of the cases due to sporadic causes, and 62.8% due to genetic causes (47.1% recessive, and 15.7% dominant). Ambient noise level and suddenly high level noise can be effect the partial deafness. Result of solution of the full deafness with operation with cochlear implant, children can partially hears and can understand the music and instrument.

Classroom acoustics are generally overlooked in world education. Noise, echoes, reverberation, and room modes typically interfere with the ability of listeners to understand speech and music. The effect of all of these acoustical parameters on teaching and learning in school needs to be researched more fully. These acoustical effects are commonplace in new as well as older schools, and when carried to an extreme, can greatly affect a child's ability to understand (Barton, 1989; Blair, 1990; Crandell, 1991; Finitzo, 1988). The precise reason for overlooking these principles needs to be studied more fully. Recently, however, acoustic principles have been clarified, and technologies for measuring room acoustics and providing sound systems have become available to solve many of the acoustical problems in classrooms (Berg, 1993; Brook, 1991; D'Antonio, 1989; Davis & Davis, 1991; Davis & Jones, 1989; Eargle, 1989; Egan, 1988; Everest, 1987, 1989; Foreman, 1991; Hedeen, 1980). Also, it can be said that especially the music classroom acoustics in the music school is the future criteria for the design and renovation of learning spaces. [10]

2. Medical facts - what is the partial deaf children limits

For the considering music schools of any form of acoustical treatment, medical facts are worth consider. Many children between 5-15 years old have transient hearing loss due to recurring ears infections. Ear infections (Otitis Media) constitute the most frequent diagnosis for children. According to Uludag University and US National Centre for Health Care [6] research estimates that there are 14 cases annually approximately for every 100 children between 5-17. Ear infection results in hearing loss these ranges from slight to moderate, with an average loss between 20 -35 dB. A normal child's speech and playing any instrument perception can also decline considerably as a result of common cold. Therefore, music classroom acoustic criteria (MCAC) should take into account such hearing impairment, as children with hearing deficiency are often undetected at an early age.

Speech understandability generally depends on the understanding of consonant letters like (whistle, miss). So, at the lecture it is important to press consonant letters is much more effective than to shout for partial deaf student. Generally consonant letters are high frequencies sounds and if student can't understand high frequencies sounds also can't understand general consonant letters and proportion of understandability loss. For example, it lower frequencies than 500 Hz. are used in postsynching %7 percent of speech can understand, but if this frequency is higher than 500 Hz. %96 percent of speech can understand. So, understandability according to the frequencies which are;

Understandability	under	over
250 Hz.	%2	%98
500 Hz.	%7	%96
1000 Hz.	%40	%86
2000 Hz.	%70	%75

Table 1: These proportions found with the standards measurements.

Note	Frequency (Hz)	Wavelength (cm)
C_0	16.35	2100.
$C^{\#}_0/D^b_0$	17.32	1990.
D_0	18.35	1870.
$D^{\#}_0/E^b_0$	19.45	1770.
E_0	20.60	1670.
F_0	21.83	1580.
$F^{\#}_0/G^b_0$	23.12	1490.
G_0	24.50	1400.
$G^{\#}_0/A^b_0$	25.96	1320.
A_0	27.50	1250.
$A^{\#}_0/B^b_0$	29.14	1180.
B_0	30.87	1110.
C_1	32.70	1050.
$C^{\#}_1/D^b_1$	34.65	996.
D_1	36.71	940.
$D^{\#}_1/E^b_1$	38.89	887.
E_1	41.20	837.
F_1	43.65	790.
$F^{\#}_1/G^b_1$	46.25	746.

Table 2: Some example ffrequencies for equal-tempered scale: This table created using A_4 = 440 Hz Speed of sound = 345 m/s = 1130 ft/s = 770 miles/hr ("Middle C" is C_4) (MTU Physics Home)

Understandability proportion additionally effected from masks, reverberation (echo effect), and ambient noise.

Here we can understand that, at the music classroom instruments and music types are important for partial deaf student for understanding the music notes, feeling the esthetic of music. For example the oboe, cello, drum playing can be compare with playing church organ, flute, violin. Also Bach's church music can compare with Ravel' Bolero, Carmen, Carmina Burana's women and man sounds Fig.[2]. For the finding music notes frequencies Eq[1] can be used. The basic formula for the frequencies of the notes the equal tempered scale is given by;

$$f_n=f_0*(a)^n \quad (1)$$

where

f_0 = the frequency of one fixed note which must be defined. A common choice is setting the A above middle C (A_4) at f_0 = 440 Hz.

n = the number of half steps away from the fixed note you are. If you are at a higher note, n is positive. If you are on a lower note, n is negative.

f_n = the frequency of the note n half steps away.

$a = (2)^{1/12}$ = the twelth root of 2 = the number which when multiplied by itself 12 times equals 2 = 1.059463094359..)

3. Musical Acoustics Research and Production of Musical Sound According to Instrument

3.1. Musical sound sources and instrument types

Classifying musical instruments is according to the nature of the primary vibrator. These are: 1.String instruments, 2.Wind instruments, 3.Percussion instruments or; a.Chordophones, b.Aerophones, c.Idiophones, d.Membranophones. Additionally can be say; Electronic synthesizer, the digital computer, human voice.

One another classification of instruments is according to the nature of the feedback like; Payer delivers energy to the primary vibrator; string, membrane, bar or plate, and thereafter as little control over the way it vibrates. Percussion, Plucked string, Struck string. Continuing flow of energy is controlled by feedback from the vibrating system, Wind and bowed string instruments. Pressure feedback opens or closes the input valve. Ex. Brass and reed woodwinds. The input valve flow controlled. Ex. Flutes or flue organ pipes. Pulses on the string control the stick-slip action of the bow on the string. Ex. Bowed string instrument. [11, Rossing, Thomas D.]

b. Reach of Sound from Source to the Child

We have to deal with two types of sound which are wanted or expected sound and unwanted or unexpected sound. First type is the sound which transmitted from musical instruments which by player her or himself. Second type is the sound which transmitted from outdoor noise or another players' music and masked our music. Also, the reach of the instrument sound to the students can be direct and indirect or reflected sound. In the music classrooms because of the volume of the room, reflected sound is much more important then other closed areas. Here, generally can be said that best hearing child can recognize of the sound between the church organ which have minimum frequency level of 20 Hz. to dog bark which have 20.000 Hz. frequency. Speaking is generally between 500 Hz. – 2000 Hz. But general music instrument's frequency intervals and sound pressure level interval is very wide. This is the means that efficient protection from the reverberation and transmission gain from outdoor needs extra precaution. If these protections don't do in classical education room, outdoor sound, distract the children's attention and create the problem. If this outdoor sound reach the music classroom, this sound nor only distract the children attention but also they can't understand the sensitivity of musical note and the music.

Figure: 3 Example from Hacettepe Univ. Music School

When looking at the partial deaf children in the music rooms problems are getting higher. When hearing impairment begin firstly hearing of high frequencies is lost. Additionally ladies and children sounds' frequencies are generally higher than man voice. This means that understanding disabilities of children voice is more difficult than adult man not only for the children but also for the teacher. Also, at the music education sound pressure level intervals and frequency intervals are very wide and confusing the music notes is easy at the high frequency notes. This problem can change according to musical instrument type and understanding the speech and song words. Additionally, if the room is not the dead room or reverberation time is long and transmission loss is not enough, confusion of the notes and understanding disabilities of the words of song will be high.

4. Architectural Solution for Music Education Schools

Architects have to aware of acoustical problems when designing the school. Architectural acoustical design need inter discipliner working especially special buildings. Music Schools are already special buildings but also music schools and music classrooms for partial deaf students need more special conditions. For understanding of this condition architect have to work like a music compositor with doctors, musicians, engineers and workers.

4.1. Designing Criteria for Music Education Room

Music schools have to include not only design for speech but also design for music. This designing require the solution for both factor. When designing a room for speech, the most important criterion is that the speaker should be distinctly and readily heard by all members of the audience. A quantitative measure of the degree of clarity at various positions in the room can be obtained by articulation tests.

Here "the percentage articulation index (PSA)" give the performance of correctly hearing. In a room where the PSA is about 75 %, the listener has to concentrate to understand what is said while below 65% the intelligibility is too poor. Here there are four types of factors which affect the clarity of speech. Firstly, the background noise level which can mask the design sound. This level should be kept below 30 dBA. Secondly, the sound pressure level produced at the listener's ear and the speaker. Here the shape and the volume of the music room are effective factors for acoustical design. Thirdly and the perhaps most important factor for music classroom acoustics is reverberation time. RT in normal speech the syllables and the music pattern follow each other with rapidity. If not, each syllable and pattern decays fairly quickly it will tend to mask those following. Additionally, the room shape and using covering materials are effect the music classroom acoustics, although providing this has been designed to avoid echoes and dead spots and each member of the audience has a good view of the speaker then the articulation should not be effected.

Also, we can add the one more factor for the music school and classroom design. It can be said that the most important different between speech educational room and music educational rooms are frequencies of ambient sound. Human speech sound frequencies between 500 Hz. And 2000 Hz. This can be change according to children's age. But music instrument sound frequencies can be change. For example a violin sound frequencies can change between 200 Hz. And 5000 Hz. [11].

The acoustical environment of a music classroom (MC) is a critical factor in the academic, psychoeducational, and psychosocial achievement of children with normal hearing and with hearing impairment. There are several acoustical variables, such as noise, reverberation, and speaker-listener distance, which can deleteriously affect speech and especially music perception in classrooms. Moreover, the discussion examines the effects of these variables on the speech perception abilities of both children with normal hearing and children with hearing loss. Finally, appropriate acoustical criteria are suggested for children in educational settings.

Because of the aesthetic and emotional criteria judgments, are involved to state criteria for good listening conditions for music is much more difficult. The design of classroom for music is therefore as much an art as a science, because of the criteria are almost totally subjective making them very difficult to define and also very difficult to measure. Especially for music classroom the sound absorption, reflection, rarefaction and transmission must be considered with frequent band analysis. Because of the classic education schools and classroom generally speech frequency (500Hz, 1 kHz ve 2 kHz; ANSI-1989) can be acceptable but for music school and classrooms these frequency band interval is too wide. Perhaps classrooms cad be grouped according to instruments.

1. stringed instruments room
2. woodwind instruments room
3. brass instruments room
4. piano and other stringed keyboard instrument room
5. orchestra room

Aspects of auditory brain stem responses (ABR) and pure-tone behavioral audiograms were compared in patients with cochlear hearing loss. Click-evoked ABR thresholds appeared to be related most closely to the audiometric thresholds at 2000 and 4000 Hz, with relatively poor agreement at either 1000 or 8000 Hz.

4.2. *.Importance of Absorption and Transmission in the Music Classrooms*

At the research and measurement seem to be that because of the frequency differences and differences of sound levels, absorption and transmission loss are very difficult against to very important. For the solution, acoustical design and decisions have be prepared before the beginning architectural design. Because of, music schools are also special buildings which need special systems. If we only deal with regular building eq. 2 would be enough for us because speech understandability would be most important factor for us. Approximately sound transmission loss for 500 Hz.

$$R = 15.4 \times \log(m) + 10\ ;\ R = 15 \times \log(4m) \quad (2)$$
$$R = 19 \times \log(m)$$

Panel's m^2, weight of dividing panel, interior and outdoor sound frequency affects the Transmission Loss. At the music schools sound pressure levels difference and frequency differences are too wide. At the Eq. 3,4 and 5 approximate calculation is given according to difference frequencies.

$$R = 18 \times \log(m) + 12 \times \log(f) - 25 \quad (3)$$
$$R = 20 \times \log(m) + 12 \times \log(f) - 27 \quad (4)$$
$$R = 20 \times \log(m) + 20 \times \log(f) - 46 \quad (5)$$

M^2 : weight
F: frequency

These results are apptoximate becuse equations are empirical.

5. Case Study from Turkey

For an example of music school, Hacettepe University Music School had been researched and measured sound levels and also researched other music schools, music classrooms and classic classrooms. At the measurements, it was seen that transmission loss was very insufficient and ambient noise which is especially outdoor sound gain is too much. Figure 4 and 5 and Tables 4 and 5 are showing the differences of sound level meter at different music rooms.

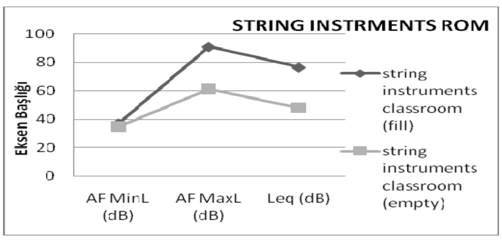


Figure 4: sound level differences between full and empty room for string instruments room.

classroom	AF MinL (dB)	AF MaxL (dB)	Leq (dB)
wind instruments classroom (full)	35	94	82
wind instruments classroom (empty)	33,1	71,2	50,6

Table 5: sound level differences between full and empty room for wind instruments room.

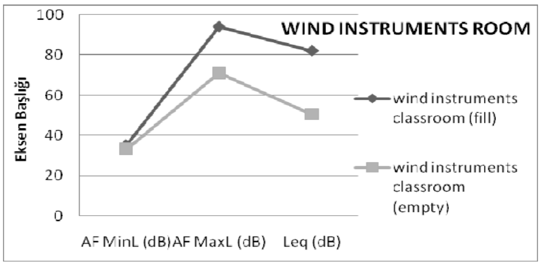


Figure 5: sound level differences between full and empty room for wind instruments room.

classroom	AF MinL (dB)	AF MaxL (dB)	Leq (dB)
string instruments classroom (fill)	37	91	76,5
string instruments classroom (empty)	34,8	61,5	48,1

Table 4: sound level differences between full and empty room for string instruments room.

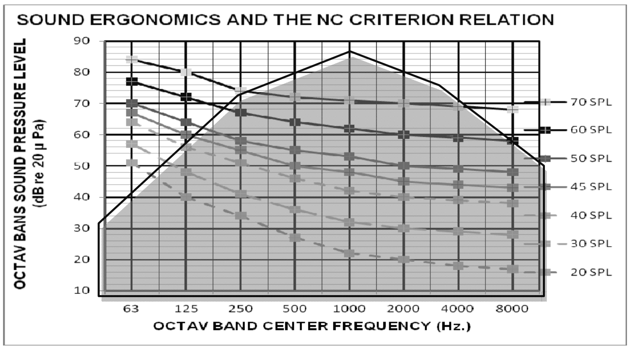
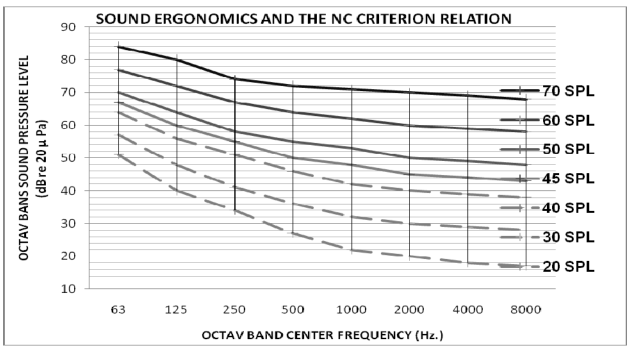


Fig. 6 Orchestra room sound pressure levels with the function of frequency. [9]

Also, according to approximate calculation for general classroom RT are between 2-7 sn. Which is very much high not only for music classroom but also for regular classroom. When look for the sound pressure level for classroom



= Acceptable levels
= Limit for occupation
= limit for industry
= noisy level

Figure 7: NC 45 curves' ergonomic limits (according to EPA, ILO, WHO) [5]

At the Doctorate thesis Mrs. F.B. Kocyigit researched the needed sound pressure levels for different occupations for EPA[12], WHO[13], ILO, FICON and European Standards, NPC acceptable Sound Pressure Levels. According to this research education area have to be under the limit of [NC 45 Curves]. When looking at the example seem that if the classroom is empty sound pressure level can be near to acceptable but if there is a lecture in room finding this limit impossible with this reverberation time.

ORGANIZATION	SOUND PRESSURE LEVEL	AREA CRITERIAS
EPA Limits	$L_{dn} \leq 55$ dB (outdoor)	Max. Limits for public health
	$L_{dn} \leq 45$ dB (indoor)	
WHO limits (1995)	$L_{eq} \leq 50$ /55 dB (outdoot daytime)	Recommended limits, Education area.
	$L_{eq} \leq 45$ dB (outdoor midnight)	
	$L_{eq} \leq 30$ dB (bedroom)	
	$L_{max} \leq 45$ dB (bedroom)	
US Interagency Committe (FICON)	$L_{dn} \leq 65$ dB	Living room limits
	$65 \leq L_{dn} \leq 70$ dB	
European Rules for Traffic	$L_{eq} \geq 65$ or 70 dB (daytime)	Adjustable according to measurements.

Table 6: EPA[12], WHO[13], FICON and European Standards acceptable Sound Pressure Levels [5]

Compare the Table 6 and Figure 6 seem that example rooms are very far fromacceptable sound pressure levels for healty music student. If we think to use these areas for partially hearing disabled children (PHSC) seem that these problems have to solve immediately.

Additionally, these figures explain us outdoor sound is much more effective than other schools. If classrooms are very narrow this problem is getting more. Especially another effective condition is different types of instruments' classrooms are must be different zones. Here the instruments intensity and frequencies are affecting the problems.

6. Conclusion

Music schools are special buildings, and handicapped schools are also special buildings which have to solve the problems with different disciplines. Also there are too many acoustic problems in music schools, not only for handicapped children but also regular education students. Especially, because of sound levels are too high according to regular education classrooms envelopes (walls, floor and ceiling) have to cover with transmission loss materials. This also important for prevent from outdoor sound. Not only for understandability of speech and music notes but also for feeling the music. Here we tried to inquire also the problems of partial deaf students' music education problems. Using the architectural solutions for these rooms can be helped both the regular and handicapped children.

Acknowledgement

This research is one part of serial research which tried to solve hospital sound ergonomics with architect, mechanical eng., electrical eng., chemical eng., doctors, and musician.

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