Technology, 13(2), 107-117, (2010)

TECHNOLOGY

ACOUSTICS IN THE UNDER TEENAGED STUDENT' MUSIC CLASSROOMS

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Abstract

Music schools need some special acoustical design for better education. If this is also for under teenaged children, effect is more important. This research is about musical education for under ten years old students. At this point architectural acoustic design acquires importance, 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 under teenaged students or not. Here the first glance is whether some additional components are needed for good classroom acoustics for good education in the ANSI Standard S12.60 2002 for classroom acoustics, and the cost impact of the Standard. Childhood hearing and understanding capacity is seen differenciate from adults hearing and understanding sound capacity. 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 under teenaged need more acoustically controlled room to amplify the instrument sound for improved hearing capacity.

Key words: under teenage children, music education, architectural acoustic, classroom

1. Introduction

Under teenage students have to be discussed under several groups like 0-2 years old, 3-6 years old and 7-12 years old groups according to cochlea and dependengly hearing capacit developing. At this research 3-6 and 7-12 years old students has been discussed. For this discussion several aspect which noise propogation by under teenage children and effect of ambient noise at education ares has been ealuated. International researhes shows that ambient noise level and sudden high level noise can be directly effect the partial deafness. After the solution of the full deafness with operation with cochlear implant, children can partially hear and can begin to feel the music.

Generally because of the cost and crowded, classroom acoustics are generally overlooked in world education. In spide of the fact that noise, echoes, reverberation, and room modes typically interfere with the ability of listeners to understand speech and music, this subject is very has been few researhed. 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. Additionally, can be said that, learnin period for under teenager is longer than over teenager student ambient noise level in nursory and primary school music room's noise control is much more important than high and fine art schools'.

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2. Speech and Music Understandability Limits for Under Teenage Students

2.1. Speech' and Chorus' Effects in Music Rooms

Both of two conditions not only needs acoustics control buth also noise sources in rooms. In lecture room; at the period of lecture time by teacher, if students talk at the same time with teacher, their sounds embroil teacher's sound, at this condition students' sound mask the teachers talks. (same condition happens at music rooms also). Student who stay backside the class are affected from masking conditions and can not easily understand the lecture. Bored student who can't understand teacher, began to talk on-their-own. This conditions cause the enhance of the murmur at the backside of the room.

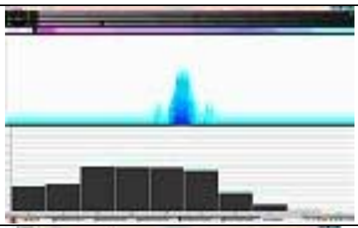
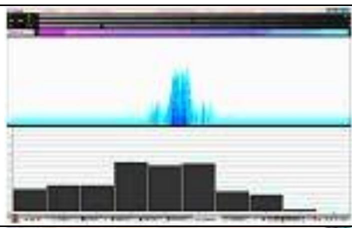
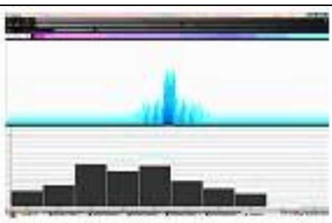
2.1.1. Speech' Effect on Music Rooms

Speech understandability generally depends on the understanding of consonant letters like whisper, rustle, and swish. Meanly, pressing consonant letters is much more effective than to shout for partial understandability. Generally consonant letters are high frequencies sounds and if student can't understand high frequencies sounds also can't understand genral consonant letters and proportion of understandability loss. For example, at lower frequencies than 500 Hz. are used in postsynching %7 persent 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 proportion additionally is affected from masks, reverberation (echo effect), and ambient noise.

Table 1: These proportions found with the standards measurements.

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

Table 1 also shows that, at the music classroom, instruments' frequencies and music types are important for under teenage students to understanding the music notes, feeling the esthetic of music. For an example; the oboe, cello, drum playing can be compare with playing flute, violin. Also Bach's church music can compare with Ravel' Bolero, Carmen, Carmina Burana's women and man sounds. For the finding music notes frequencies Eq. 1 can be used.

L	MAN	WOMEN	CHILDREN
A			
B			
C			

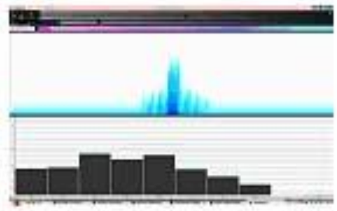
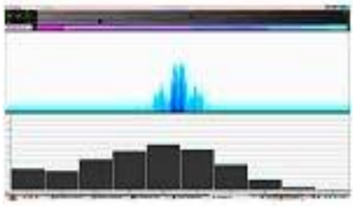
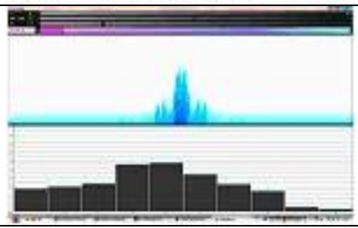
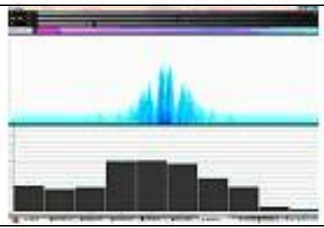
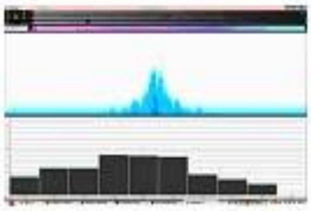
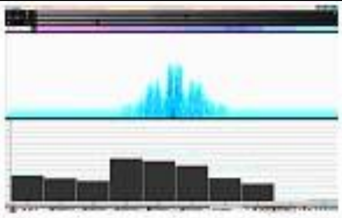
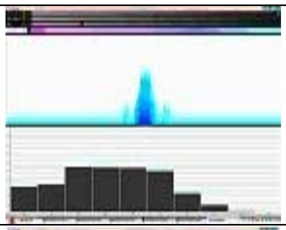
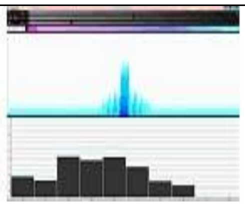
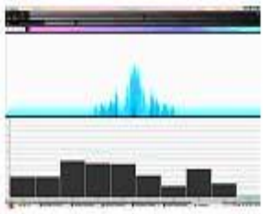
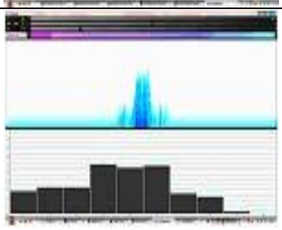
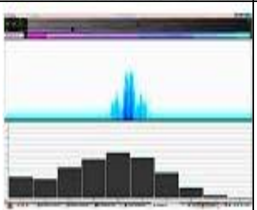
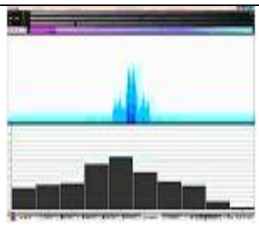
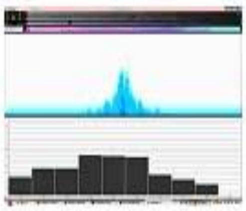
D			
E			
F			
G			
H			

Figure 1. Comparing man, women and child’s sound frequencies for vowel and consonant.

	CONSONANT		**VOWEL**	
	A	**E**	**B**	**H**
M				
W				

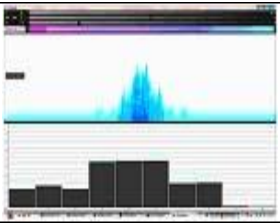
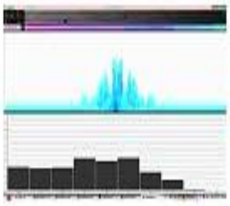
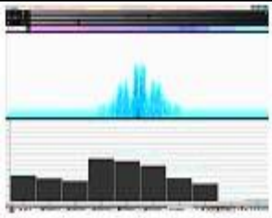
C				

Figure 2. Comparison of vowel and consonant letters with the funtion of gender and age (man, women and child)

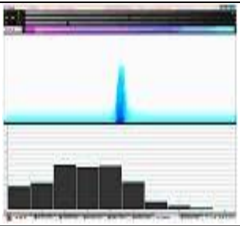
	O	**U**	**İ**	**E**
M				

Figure 3. comperison of narrow vowel and wide vowel letters frequencies with the man noise.

Figure 1,2,3 show the difference frequencies of man, women and under teenage children voise. At this reseach, becuse different words including different letters only the letters are tested. Because of the voices intensit is accepted constant, upper part of figures' crest are similar. But, Figure 4 shows the comparison of high voice and low voice, because at music period chorus' voise is changing from low to high.

2.1.2. Effect of Chorus' on Music Room

The period between chorus songs vocal onset and stimulus onset was extracted to measure the mean F_0 values for each condition. Statistical results showed that on average, subjects spoke at 275 Hz for the high voice F_0 condition and 209 Hz for the low voice F_0 condition [$F(1,58)=35.437$, $p<0.0001$]. From 15 subjects across two voice F_0s, two stimulus magnitudes, and two stimulus directions, there were 120 responses (15x2x2x2). 93 responses opposed the stimulus direction, and 22 responses followed the direction of stimulus. 5 of 120 responses did not meet our criteria of validity and were declared to be non-responses. A chi-square test revealed a statistically greater number of non-response and "following" responses in the low voice F_0 compared to the high voice F_0 condition ($x_2=6.259$, d.f.=1, and $p=0.012$). The distribution of opposing, following, and nonresponses was even across stimulus direction and stimulus magnitude. [6]

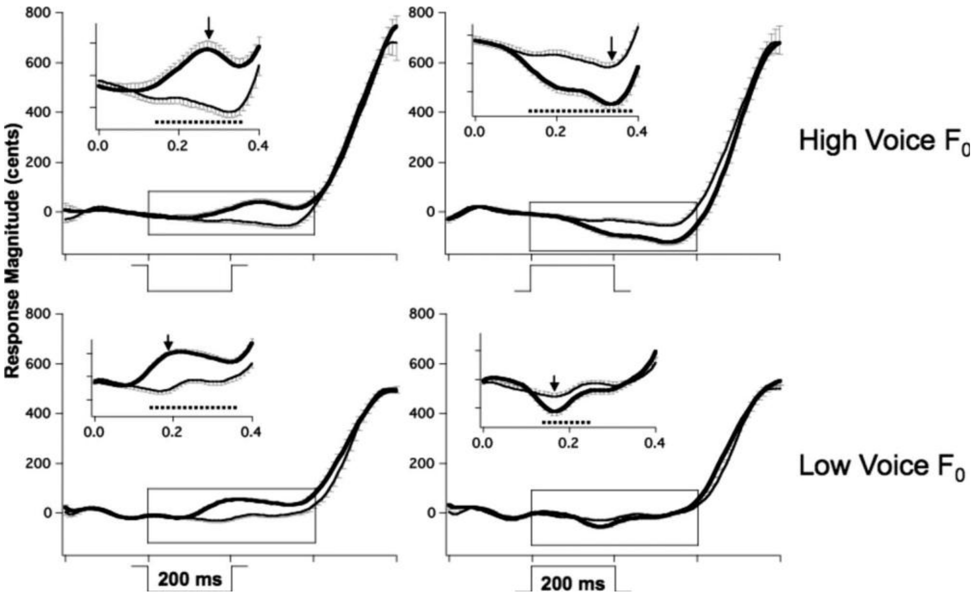


Fig. 4. Representative vocal responses to 200 cent pitch-shifted stimuli as a function of stimulus direction at a high (top) and a low (bottom) voice F_0, respectively. Thick lines represent the averaged F_0 contours of

responses to pitch-shifted feedback, and thin lines represent contours for control trials. The solid vertical arrow indicates time where the response magnitude was measured. The dashed horizontal line represents the onset and offset of the response, and response latency is indicated by the start of this line. The inset shows an expanded portion of average waves. Error bars attached to the contours represent the Standard error of the mean for a single direction. Boxes at the bottom indicate the time and the direction of the stimulus.

Figure 4 shows the representative vocal responses to pitch perturbations as a function of stimulus direction at a high and a low voice F_0. As shown in this figure, larger vocal responses occurred when subjects spoke the phrase at a high voice F_0 compared to a low voice F_0. Table 2 presents the average and standard deviations (SDs) of the response magnitudes and latencies across all conditions. Although these data lend themselves to repeated-measures ANOVAs (analysis of variance), factorialANOVAs without repeated-measures were used in the present study to account for missing data and unequal cell size.A three-wayANOVA performed on the response magnitude indicated a significant main effect for voice F_0 [$F(1,81)$ =11.817, p=0.001] but not stimulus magnitude [F(1,81_=0.916, p=0.341] or stimulus direction [$F(1,81)$=2.062, p=0.155]. The high voice F_0 produced significantly larger response magnitudes (38±26 cents) than the low voice F_0 (23±16 cents). No significant interactions were found across all conditions.

Table 2. Averaged response magnitude SD in cents and response latency SD in ms as a function of voice F_0, stimulus magnitude, and stimulus direction.

		Response magnitude		Response latency	
		High voice F_0	Low voice F_0	High voice F_0	Low voice F_0
100 cent stimuli	Up	27 (18)	19 (13)	138 (61)	165 (77)
	Down	37 (24)	28 (18)	117 (48)	152 (66)
200 cent stimuli	Up	40 (25)	22 (11)	106 (38)	124 (67)
	Down	48 (33)	23 (22)	115 (58)	140 (63)

A three-way factorial ANOVA on the response latency revealed a significant main effect for voice F_0 [F (1,81)=4.251, p=0.042] but not for stimulus magnitude [F (1,81) =2.967, p=0.89] or stimulus direction [F(1,81)=0.029, p=0.866]. Faster response latencies were generated at the high voice F_0 (119±52 ms) than the low voice F_0 (146±68 ms). No significant interactions were found in the response latency across all conditions.

2.2 Musical Acoustics Research and Production of Musical Sound According to Instrument

2.2.1. Musical sound sources and instrument types

Classifying music and 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;

- The player 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.

$$\textbf{Freq. (hertz)} = \textbf{ref.} \times 2^{((\text{octave} - 4) + (\text{tone} - 10)/12)} \quad \textbf{Eq. 1.}$$

Table 3: B>referance at 440 Hz. 4th. Octave if A note is, we can calculate from C to B from1 to 12.

Nota	**Oktav**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
C	32,70	65,41	130,8	261,6	523,3	1047	2093	4186
C #	34,65	69,30	138,6	277,2	554,4	1109	2217	4435
D	36,71	73,42	146,8	293,7	587,3	1175	2349	4699
E b	38,89	77,78	155,6	311,1	622,3	1245	2489	4978
E	41,20	82,41	164,8	329,6	659,3	1319	2637	5274
F	43,65	87,31	174,6	349,2	698,5	1397	2794	5588
F #	46,25	92,50	185,0	370,0	740,0	1480	2960	5920
G	49,00	98,00	196,0	392,0	784,0	1568	3136	6272
A b	51,91	103,8	207,6	415,3	830,6	1661	3322	6645
A	55,00	110,0	220,0	440,0	880,0	1760	3520	7040
B b	58,27	116,5	233,1	466,2	932,3	1865	3729	7459
B	61,74	123,5	246,9	493,9	987,8	1976	3951	7902

Table 4: Harmonic

Harmonik	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Frekans	32,7	65,4	98,1	130,8	163.5	196,2	228,9	261,6
Nota	C	C	G	C	E	G	B b	C

2.2.2. 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 herself or himself. Second type is the sound which transmitted from indoor noise, outdoor noise or another players' music. Also, the reach of the instrument sound to the students can be two way. Direct sound 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 recognise 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 be sensitivity for musical note and the music.

When looking at the under teenaged students in the music rooms, problems are getting higher. Additionally under teenaged children sounds' frequencies are generally higher than ladies (ladies voice frequencies can be near to children' voice) and man voice. Aditionally 2-7 years old children's sound' frequency generally higher than 7-12 years old children. Especially boy's sound' frequencies getting lower and lower till 18 years old. This means that understanding and control under teenaged children' voice is more difficult than adults not only for the other children but also for the teacher who have especially hearing problem at frequency. 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.

3. Architectural Evaluation for Music Education Schools

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

3.1. 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 and propogation sound with music. Human speech sound frequencies between 500 Hz. And 2000 Hz. This can be change according to childrens' age. But music instrument sound frequencies can be change. For example a violin sound frequencies can change between 200 Hz. And 5000 Hz. **[7]**

The acoustical environment of a music classroom is a critical factor in the academic, psychoeducational, and psychosocial achievement of under teeages 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 or under teenages children. 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.

3.2. 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.

Eq. 2: Approximately sound transmission loss for 500 Hz
.
$R = 15.4 \times \log(m) + 10$; $R = 15 \times \log(4m)$; $R = 19 \times \log(m)$

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 approximate calculation is given according to difference frequencies.

Eq. 3: Approximate equation according to frequencies.

$R = 18 \times \log(m) + 12 \times \log(f) - 25$; $R = 20 \times \log(m) + 12 \times \log(f) - 27$

$R = 20 \times \log(m) + 20 \times \log(f) - 46$
M^2 : weight
F: frequency
These results are apptoximate becuse equations are empirical.

4. Case Study from Turkey

Hacettepe University Conservatory had been researched and measured as an example of music school. Also Karabuk Universit Fac. Of Fine Art and Design Music Department's working rooms and studios are measured. At the measurements, seems that transmission loss was very insufficient and ambient noise which is especially outdoor sound gain is too much. Figure 1 and 2 are showing the differences of sound level meter at different music rooms.

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

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

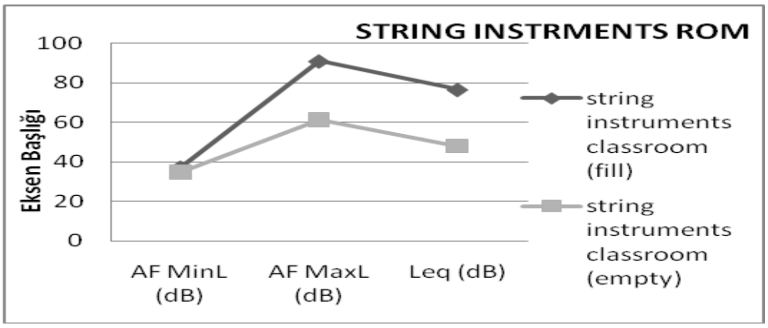


Figure 5: sound level differences between full and empty room for string instruments room.

Table 6: sound level differences between full and empty room for wind instruments room.

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

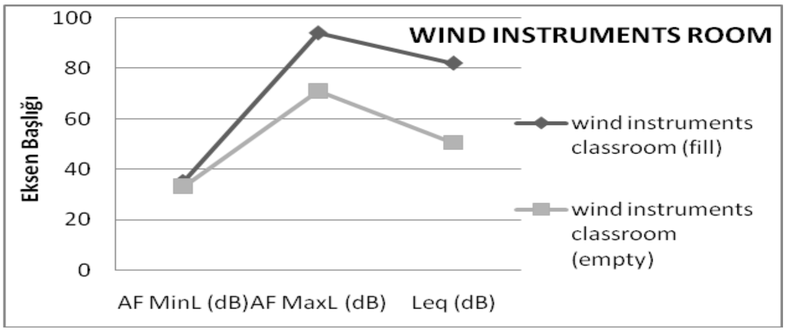


Figure 6: sound level differences between full and empty room for wind instruments room.

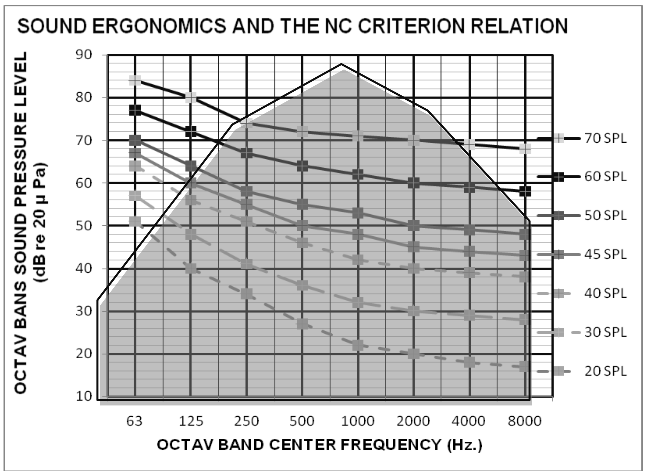


Fig. 7 Orchestra room sound pressure levels with the function of frequency.

These figures explain us because of the highway's traffic noise which is forefront and backside of Hacettepe University's Music School's getting high outdoor noise. This noise is much more effective than other researched schools. If classrooms are very narrow to littoral of garden, 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 effecting the problems.

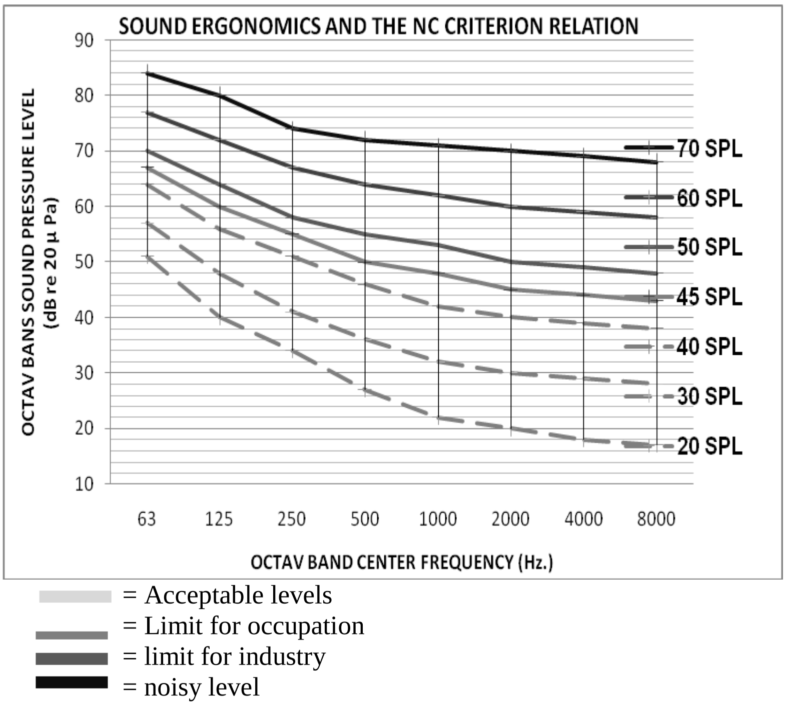


Figure 8: NC 45 curves' ergonomic limits (according to EPA, ILO, WHO) Kocyigit, Filiz Bal Thesis of Doctorate 2003

5. Conclusion

Nursary and primary schools are special buildings andespecially music classrooms also have to be under control by different disciplines. There are too many acoustic problems in music class, not only for nursary school children but also for primary school students.

For the ambient noise not only from indoor sound sources but also the outdoor sound sources getting importances at this point which have to be controlled. Chorus, organs and uther music enstrument sounds not only easily disturb each other but also regular education class. These noise not only transmitted by airborne but also by structure born. When the wind instruments like flute etc. and percussion instruments like chorus sound, reach with airborne, string instruments like drums, piano and similar organs' sound transmitted by structure borne. 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 inquired also the problems of under teenager students' music education problems. As we seen figures teenager childrens sound frequencies higher than adults persons eventhough to be women. Whenever adults sound frequency interval generally between 500 – 1000 Hz. Children' sound frequency interval higher than 1000 Hz. (can be say 750 – 2000 Hz.) High frequeny sound more effected for human psichological and physological health. Under teenager student's teachers are exposured to this noise for approximately nine hour every day (not only at classrooms but also at noon break). Temporary and perpetual deafnes,easily exhaustion, nervousnes ... ect. are the frequently seen problems for teachers. This condition demands different solutions accoring to frequency band intervals which related to using subject in classrooms.

Acknowledgement

This research is the beginning of serial research which tried to solve with architect, mechanical eng., electrical eng., chemical eng., doctors, and musician.

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