ENGLISH VERSION..

Una mirada a los criterios de diseño acústico de la infraestructura educacional en Chile

A review of acoustic design criteria for school infrastructure in Chile

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Abstract

Since oral communication is the main means we use to learn, acoustics becomes one of the most important attributes of the architectural design of classrooms. Adverse acoustic conditions in the classroom negatively affect the learning, performance and cognitive development of students. In year 2015 the Ministry of Education introduced acoustic design criteria for learning spaces. This article presents a review of these criteria based on a comparison with international regulations and considering the database of the Santiago's urban noise map. The results show that the current acoustic criteria for educational settings in Chile present several shortcomings with respect to international standards. It is also observed that more than 70% of educational establishments in Santiago are exposed to environmental noise levels that lie outside the range of application of the criterion.

Keywords: *Classroom acoustics; Educational infrastructure; Façade noise*

Resumen

Desde que la comunicación oral es el principal medio que utilizamos para aprender, la acústica se vuelve uno de los atributos más importantes del diseño arquitectónico de las aulas. Las condiciones acústicas adversas en las aulas afectan negativamente el aprendizaje, el desempeño y el desarrollo cognitivo de los estudiantes. En el año 2015 el Ministerio de Educación introdujo criterios de diseño acústico para los espacios educativos. Este artículo presenta una revisión de dichos criterios realizada mediante una comparación con la normativa internacional y considerando la base de datos del mapa de ruido urbano de Santiago. Los resultados muestran que los actuales criterios acústicos para los espacios educativos en Chile presentan falencias con respecto a la normativa internacional. Además se observa que, con los actuales niveles de ruido urbano, el criterio de diseño acústico para los espacios educativos del Ministerio de Educación no se puede aplicar a más del 70% de los establecimientos educacionales en Santiago.

Palabras clave: Acústica de espacios educativos; Infraestructura escolar; Ruido de fachada

1. Introduction

It is usually accepted that certain features of the architectural design of educational environments such as lighting, color, ventilation, temperature and acoustics, among others, have an influence on the attitudes, behavior and achievement of the students (Lewinski, 2015) (Maxwell, 2016) (Tanner, 2009) (Uline and Tschannen-Moran, 2008). However, the implications of having quality learning environments go beyond the comfort in the classroom. According to the Organization for Economic Cooperation and Development (OECD), improving the students' achievement directly increases the Domestic Gross Product (GDP) per capita of a country (OECD, 2010). Evidence shows that an increase of half a standard deviation in the individual performance in mathematics and science entails a 0.87% increase of the annual growth rate of the GDP per capita. This relationship between quality learning environments, academic achievement and economic growth is a virtuous circle that justifies, in the long term, the implementation of public policies on this matter.

In 1997, the Chilean Ministry of Education (MINEDUC) subscribed the UNESCO agreement with the purpose of optimizing public investments on school infrastructure. One of the outcomes of this agreement was the development of Design Guidelines for Learning Environments aimed at educational projects in the country (MINEDUC, 1999). These documents were prepared together with the Architecture Department of the Ministry of Public Works, and their objective was to establish general design criteria and recommend architectural programs for educational institutions, according to the climate regions of the country and the school educational levels.

At the time, acoustics was an architectural attribute of learning environments that was not included in the design guidelines. Proper acoustics is essential in the schools, since verbal communication is still the primary means to teach and learn in the classrooms. In fact, unfavorable acoustic conditions in learning environments, such as excessive ambient noise and reverberation, interfere in the verbal communication and have adverse effects on learning, the academic achievement and the cognitive development of the students (Klatte et al., 2013).

It is a fact that children do not listen as adults do. A number of functionalities of the auditory process continue to develop during childhood or adolescence (Werner, 2007). This lack of neurological maturity in the auditory process is

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evidenced by a reduced capacity of the students to process hearing functions such as: the spatial location of the sounds (Moore, 2002), the categorization of phonemes (Hazan and Barret, 2000), the selective auditory attention (Jones et al., 2015), the perception of speech in the presence of noise (Jacobi et al., 2017) and the recognition of speech under noisy and reverberating conditions (Neumann et al., 2010) (Koopmans et al., 2018). For example, in order to obtain the same performance in speech intelligibility tests, a 6 year old student requires that the difference between the classroom's environment noise level and the teacher's voice level is 7 dB higher than that required by an 11 year old student (Bradley and Sato, 2008). Only towards the end of their teen years, children achieve the adult auditory performance to identify words in the presence of noise. On the other hand, the lack of linguistic skills also plays against the students' hearing. Their limitations in the lexical access reduce their capacity to recognize words in the presence of noise (Kaandorp et al., 2016); at the same time, children are less competent than adults to use the context in order to reconstruct words degraded by the noise (Klatte et al., 2013). Under adverse acoustic conditions, children are more likely to lose auditory information than adults. This susceptibility increases among children under 13 years of age; therefore, they are considered a risk group in case of poor acoustics in the classroom (Anderson, 2008) (Flagg-Williams et al., 2011) (Shield and Dockrell, 2003).

Students educated in noisy schools learn less. The chronic exposure to noise in the classroom can reduce the learning rates of children as of 4 years old, and the negative effects on their learning are enhanced as the exposure years increase (Maxwell and Evans, 2000) (Shield and Dockrell, 2008). Noisy classrooms also reduces the students' motivation to learn (Clark et al., 2005) (Evans and Lepore, 1993). The students' academic achievement is negatively affected by a noisy classroom. The evidence reveals that noise exposure reduces the language performance (reading and writing) as well as the mathematical one (Ljung et al., 2009); it also reduces the performance in national standardized tests (Shield and Dockrell, 2003), and intellectual coefficient tests (Bhang et al., 2018). It is also suggested that the noise exposure in the classrooms affects the boys more than the girls (Hetú et al. 1990). Regarding the effects on the cognitive performance of students, the research concludes that the exposure to high noise levels in the classroom affects the attention and concentration (Evans and Lepore, 1993) (Hetú et al., 1990) (Klatte et al., 2013) (Shield and Dockrell, 2003), the short-term memory (Jianxin and Peng 2018) (Klatte et al., 2013), and the capacity to solve problems (Bhang et al., 2018) (Shield and Dockrell, 2003). The chronic exposure to noise in the classrooms diminishes the language acquisition and reduces the reading skills and reading comprehension (Klatte et al., 2013). At the preschool level, children who attend noisy classrooms show a poor use and comprehension of language, which reduces their pre-reading abilities to differentiate between letters and numbers (Maxwell and Evans, 2000). Thus, it is not surprising that students exposed to noise in the classroom need more time to learn to read (Hetú et al., 1990). Already in primary school, children who attend schools with high levels of noise show a consistent poor performance in reading comprehension (Bronzaft and McCarthy, 1975) (Clark et al., 2005) (Evans and Maxwell, 1997).

For the first time in 2015, the Chilean Ministry of Education incorporated acoustic criteria in the design guidelines for learning environments in the country (MINEDUC, 2015). Given the extraordinary relevance of acoustics in learning environments, this work presents a review of these acoustic design criteria for the educational infrastructure in Chile. The objective of this research is to determine whether the MINEDUC quality standards are sufficient to ensure a proper acoustics in the educational institutions our country. The validity of the criteria established in Chile is discussed through the comparison with acoustic criteria adopted in a number of OECD countries, and the database of the Noise Map of Santiago (Ministry of Environment - MMA 2016), which contains urban ambient noise measurements carried out in the facades of 2155 schools in the city.

2. Acoustic Design Criteria for Learning Environments

The intersection of children's yet undeveloped auditory skills with unfavorable acoustic conditions in the classrooms creates communication [1] barriers, which put students at educational risk. Based on this premise, acoustic performance criteria for learning environments are significantly different from other criteria, such as those of acoustic comfort in the energy-efficiency context. Therefore, a growing number of OECD countries has established specific acoustic criteria for learning environments. The (Table 1) summarizes the acoustic design criteria or standards for educational environments used in Chile and in other 13 OECD countries. The criterion of the World Health Organization is also included, as well as the values recommended by (Mealings, 2016), based on collected acoustic design criteria for primary school classrooms, published in international standards and research papers.

A set of parameters is used to describe the classroom acoustic performance, which allows evaluating its suitability for verbal communication. The following descriptors are used to acoustically characterize the classrooms: background noise level L_{eqAS}, reverberation time (RT), Speech Transmission Index (STI), signal-to-noise ratio (SNR), teacher-student distance, façade isolation $D_{2m,\,nT,\,w}$, airborne noise insulation of walls R'_{w}, and impact noise insulation of floors $L'_{nT,\,w}$.

Noise Level L_{eqAS}. The noise in the classroom comes from different sources outside the school, inside the school and within the classroom itself (Flagg-Williams et al., 2011). The ambient noise emanating from the school's exterior, or urban noise, comes from road traffic, vendors, airports or railways in the vicinity of the school, and the rain. The noise

[1] Noise affects the speech perception through energetic masking and informational masking. The former appears when the speech has the same spectral characteristics as the noise, and the listener is not able to differentiate between them. On the other hand, the latter appears when the noise acts as a distractor, and it is a consequence of the deficits in the auditory brain development of the children (Klatte et al. 2013). Moreover, the reverberation energetically masks the direct sound of the teacher's voice, since it extends the duration of the sound of the vowels, which then masks the consonants and reduce the intelligibility (Crandell and Smaldino, 2000).

outside the school is usually expressed in terms of the ambient noise level in the most exposed façade or daytime noise equivalent level (DNEL). The noise inside the schools, but outside the classroom, comes from activities carried out in the schoolyard, hallways and adjacent classrooms. The noise produced in the classroom itself includes the noise of services (mechanical ventilation, lighting) and the noise of equipment (projectors, computers). The noise inside the classroom is characterized as an A-weighted Equivalent Continuous Sound Pressure Level measured on a specific period of time or L_{eqAS}, and it is expressed in dB(A). The different standards do not establish the same noise level measurement conditions, but they agree in the measurement of classrooms without student and with furniture. Depending on the standard, the maximum classroom background noise ranges from 30 dB(A) to 40 dB(A), where the most recurrent criterion is $L_{eqAS} \leq 35$ dB(A).

Reverberation Time (RT). *The reverberation corresponds to the sequence of multiple and successive sound wave reflections off the classroom's inner walls and surfaces. In relation to hearing, the reverberation is perceived as a declining prolongation of the sound of the voice after it has stopped emitting a sound[2]. The reverberation time (RT) is a standardized measure of the duration of the reverberation in a space and it is expressed in seconds. Some standards, like the BB93, use the descriptor RTmid, which corresponds to the arithmetical mean of the reverberation time in the frequency bands of 500 Hz, 1 kHz and 2 kHz. The revised acoustic design standards for educational environments specify the maximum RT based on the inner volume of the classroom and/or the school level. The maximum RT inside the classroom ranges between 0.4 and 1.2 seconds, where the most frequently used criterion is RT ≤ 0.6 seconds.*

Speech Intelligibility. *This attribute represents a measure of the proportion of correctly understood words in a speech. Inside the classroom, the speech intelligibility depends on the ambient noise, the reverberation, the teacher-student distance and the characteristics of the teacher's voice. There are several descriptors for speech intelligibility, but the Speech Transmission Index (STI) is the most common for acoustics in educational environments. According to the speech intelligibility criterion, the minimum STI ranges from ≤ 0.6 to ≤ 0.75 in the analyzed international standards. The STI is also used to characterize open concept classrooms, where it is not possible to measure the reverberation time directly.*

Signal-to-noise ratio (SNR). *It corresponds to the difference, in decibels, between the sound level of the teacher's voice and the sound level of the noise in the classroom[3]. The higher the signal-to-noise ratio, the higher the intelligibility. The signal-to-noise ratio is inversely proportional to the teacher-student distance. International standards recommend a minimum SNR of +15 dB inside the classrooms.*

Noise Insulation. *The acoustic insulations of vertical and horizontal construction elements that delimit the classroom are also used as descriptors of the classroom's acoustic performance. This category includes the façade insulation $D_{2m, nT, w}$, airborne noise insulation of the walls R'_w and impact noise insulation of the floors $L'_{nT, w}$. The acoustic insulation criterion of the façade is generally specified as a function of DNEL. The criteria for airborne noise insulation of the walls and impact noise insulation of the floors are specified based on the adjacent space, that is, whether the wall or floor in question separates the classroom from another classroom, a hallway, office, etc. Among the studied standards, the minimum criterion for façade insulation ranges from 28 dB to 48 dB. The minimum criterion for airborne noise insulation of the wall separating two adjacent classrooms may vary between 43 dB and 55 dB, being 50 dB the most common value. Finally, the minimum criterion for impact noise[4] insulation between classrooms lies in the range from 48 dB to 65 dB.*

The analysis of international regulations reveals that acoustic performance criteria for educational environments show different degrees of development among the studied countries. Currently, the most advanced seem to be the British Building Bulletin BB93 (BB93, 2014), the North American ANSI S12.60 (ANSI, 2010) and the New Zealand DQLS. Among all international standards, the descriptors most used to acoustically characterize classrooms are the background noise level L_{eqAS} and the reverberation time (RT); these are minimum requirements for any acoustic design criteria aimed at educational environments. There is also a tendency to establish criteria for other descriptors, such as the minimum STI, the minimum sound insulation of the facade $D_{2m, nT,}w$ and the walls R'_w, and the minimum impact noise insulation of floors and slabs $L'_{nT, w}$. Certain standards differentiate acoustic design criteria according to the students'

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[2] The classroom reverberation affects the perception of speech by means of two mechanisms. On the one side, the reverberation energetically masks the sound of the teacher's voice, thus reducing its intelligibility. On the other hand, the reverberation can amplify the sound intensity inside the classroom by several decibels, due to the superposition of its reflected waves. Of course this amplification also includes the ambient noise in the classroom, which further contributes to mask the teacher's voice. Therefore, it is said that reverberation and noise in the classroom interact synergically against the speech intelligibility.

[3] The teacher's regular voice, measured at a 2-m distance from the mouth, reaches around 60-65 dB during a normal conversation, but increases to more than 70 dB when speaking loudly, and it can get to 80 dB when shouting. In noisy environments, persons involuntarily tend to raise their voices so that others can hear them; this reflex action is called the Lombard effect. Although it increases the SNR, raising the voice above the ambient noise can have a negative impact on speech intelligibility. The reason is that raising the voice implies to increase the sound level of the vocals, while the sounds articulating the speech, such as the consonants, could remain intelligible (Flagg-Williams et al., 2011). Likewise, studies have demonstrated that when the voice level exceeds 69 dB(A), listeners do not perceive it well and require a higher SNR to maintain speech intelligibility levels. Thus, it seems more advisable to reduce the environmental level in the classroom rather than to increase the teacher's voice level, either naturally or by means of electronic amplification, (Nelson and Soli, 2000).

[4] The value of $L'_{nT, w}$ represents the maximum noise level that can be produced in the receiving room (classroom) by a normalized impact machine located on the slab of the source room (adjacent space).

educational level, that is, preschool, primary and secondary school, and the rooms aimed at students with hearing or language impairments. Likewise, different acoustic criteria are specified based on whether the building is new or has been renovated.

Table 1. *Summary of acoustic performance criteria for educational environments used in OECD countries*

Country	Standard	Normal Hearing Classroom							Special Audition Classroom		
		L_{eqAS}	RT	STI	SNR	$D_{2m,nT,w}$	R'_w	$L'_{nT,w}$	L_{eqAS}	RT	STI
Chile	MINEDUC		0.6[a], 0.7[b]	0.6		30	50				
Alemania	DIN 18041	35	0.32logV-0.17								
Australia	AS/NZS 2107	35	0.4-0.5						30	0.4	
Bélgica	NBN S 01-400-2	35	0.35log(1.25V)			26	44	60			
Dinamarca	BR15	30	0.6	0.6		33	51	58			
Finlandia	SFS 5907:en	35	0.5-0.8				48	63			
Francia	LOI 92-1444	33	0.8[c], 1.2[d]			30	43	60			
Italia	DPCM 05/12/97	35	0.8	0.75		48	50	53			
Noruega	NS 8175	35	0.6								
Nueva Zelanda	DQLS	35	0.4[e], 0.6[f]				50	55			
Polonia	PN-B-02151	35	0.6[g], 0.8[h]				50	53-63			
Reino Unido	BB93	35	0.6[e], 0.8[f]	0.6		35	45	60	30	0.4	
Suecia	SS 02 52 68	26-40	0.4								
USA	ANSI S12.60	35	0.6[a], 0.7[b]	0.6	15		50		30	0.4	20
Internacional	OMS	35	0.6								
Rank		30-40	0.4-1.2	0.6-0.75	15	26-48	43-51	53-65	30	0.4	20
Mode		35	0.6	0.6	15		50	60	30	0.4	20
Mealings		30	0.4	0.75	15				28	0.3	0.75
6 to 7 Years		28	0.4	0.75	20						
10 to 11 Years		39	0.4	0.61	15						

[a] Classroom volume $V \leq 283\ m^3$
[b] Classroom volume $V > 283\ m^3$
[c] Classroom volume $V \leq 250\ m^3$
[d] Classroom volume $V > 250\ m^3$
[e] Primary school classroom
[f] Secondary school classroom
[g] Classroom height $H \leq 4m$
[h] Classroom height $H > 4m$

Source: (Berglund et al., 1999) (Machimbarrena and Rasmussen, 2016) (Mealings, 2016) (Mikulski and Radosz, 2011) (Rasmussen et al., 2012) (Rasmussen and Guigou-Carter, 2016) (Torchia et al., 2015) (Vallet and Karabiber, 2002) (Wróblewska, 2010)

3. Acoustics for New Schools in Chile

In 2015, The Chilean Ministry of Education established acoustic design criteria for school infrastructures built in our country. When comparing the acoustic criteria of the MINEDUC with the international standards, we observe some important shortcomings in the national regulation. Without a doubt, the most significant limitation is the absence of the criterion concerning the maximum background noise level in the classrooms. As a matter of fact, the MINEDUC acoustic design criteria do not stipulate a maximum-allowed ambient noise level in educational environments. The need to establish a maximum noise level criterion is justified by the damaging effects of noise exposure on the perception of speech and the acquisition of language and reading, and their proved negative effects on the students' academic achievement and cognitive development. According to the international standard, the background noise level in the classroom should not exceed 35 dB(A) in primary school and 40 dB(A) in secondary school.

The limitations of the Chilean standard to guarantee an adequate noise level in the classrooms get worse when reviewing the facade sound insulation criterion $D_{2m,nT,w}$. *As specified in some international standards, the minimum insulation of the façade is based on the external noise level (DNEL). In the Chilean case, the criterion requires 30 dB as the minimum insulation of the façade when DNEL is lower or equal to 65 dB(A). This façade insulation value, although within the range of the international standard, is close to the most modest values. However, the problem is that the criterion does not specify a minimum façade insulation when DNEL is higher than 65 dB(A). This omission could go unnoticed if it wasn't for the fact that, in 2016, the Ministry of the Environment updated the noise map of Santiago, this time including standardized measurements of DNEL ambient noise in the façades of 2155 kindergartens, and private and public primary and secondary schools of the metropolitan area* [5] *(MMA, 2016). According to the noise map of Santiago, 70.63% of the facilities, approx. 1572 schools, are exposed to urban noise levels above 65 dB(A), which is considered unacceptable by the environmental regulation, and consequently, the acoustic design criterion of the MINEDUC should be inapplicable.*

According to the noise map database for Santiago, the ambient noise level DNEL to which educational institutions are exposed to range from 52.5 dB(A) for those located in more quiet areas, and rises to 81.6 dB(A) in those located in noisier areas. The (Table 2) summarizes the database result analysis regarding the noise mapping in Santiago. The number of schools shown are based on the DNEL to which they are exposed to, for different educational levels. Data show that 73.38% of the preschools are exposed to façade noise levels higher or equal to 65 dB(A) and 25.9% are exposed to levels higher or equal to 70 dB(A). Likewise, 65.13% of the primary schools are exposed to DNEL noise levels higher or equal to 65 dB(A) and 27.31% are exposed to DNEL levels over 70 dB(A). In public secondary schools the situation is still more critical, since 80.41% are exposed to ambient noise levels higher or equal to 65 dB(A), while 43.81% are exposed to levels higher or equal to 70 dB(A). Finally, 78.36% of the special education institutes are exposed to noise levels higher or equal to 65 dB(A), while 28.49% are exposed to levels higher or equal to 70 dB(A). The histogram of the (Figure 1) summarizes the results obtained in façade noise measurements in educational institutions of Santiago; the axis of the abscissa represents the DNEL interval. The analysis by level or type of education did not consider adult education institutes, educational centers or other minor classifications, but they are included in the total number of 2155 institutions.

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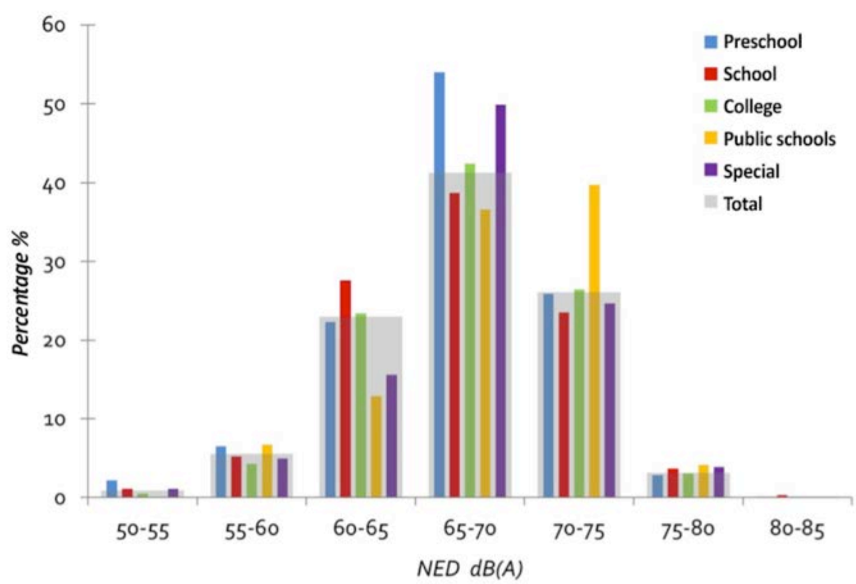
[5] The Ministry of Education does not rely on historical data regarding standardized acoustic measurement in educational institutions. Environmental comfort evaluations including non-standardized noise measurements were carried out by (Armijo et al., 2011) in eight schools of the country. They evidenced that the noise is one of the biggest problem of environmental comfort in the schools, and that the noise level inside the classrooms ranged from 45 dB(A) to 80 dB(A), while the external noise level varied between 62 dB(A) and 80 dB(A).

Table 2. *Number of educational institutions in Santiago based on the façade noise level DNEL to which they are exposed to, and the type of educational institution*

Type	Quantity	NED dB(A)						
		50-55	*55-60*	*60-65*	*65-70*	*70-75*	*75-80*	*80-85*
Preschool	*158*	*3*	*9*	*31*	*75*	*36*	*4*	*0*
School	*705*	*8*	*37*	*197*	*276*	*168*	*26*	*2*
College	*590*	*3*	*25*	*138*	*250*	*156*	*18*	*0*
Public Schools	*194*	*0*	*13*	*25*	*71*	*77*	*8*	*0*
Special	*365*	*4*	*19*	*57*	*182*	*90*	*14*	*0*
Total	*2155*	*19*	*119*	*495*	*889*	*563*	*67*	*3*

Source: Noise Map of Santiago (MMA, 2016)



Source: Self-prepared based on data from the Noise Map of Santiago (MMA 2016)

Figure 1. *Histogram of the number of educational institutions in Santiago, expressed as a percent of the total number of institutions, based on the façade noise level DNEL to which they are exposed to and the type of educational institution*

With regard to the reverberation time criterion, the MINEDUC standard homologates the ANSI S12.60, which is appropriate. As usual in other criteria, a differentiation is made based on the classroom volume RT ≤ 0.6 seconds for classrooms up to 283 m^3 and RT ≤ 0.7 s for larger classrooms. In relation to the intelligibility criterion, it was set at STI ≥ 0.6, which is consistent with ANSI S12.60, BB93 and other standards. No criterion is specified for the signal-to-noise ratio (SNR).

The criterion for airborne noise insulation of the walls was set at $R'_w \geq 50$ dB for all parameters, regardless of the adjacent area they are separating. This is positive for the walls between classrooms, but it overestimates the required insulation if adjacent areas are offices or warehouses, and it underestimates the necessary insulation if the adjacent area is a music room or a multi-workshop. Underestimating the acoustic insulation required for the walls is a risk factor concerning the compliance with acoustic quality standards in the classrooms. Moreover, overestimating the acoustic insulation of the walls may entail a waste of public resources. The acoustic design criteria of the MINEDUC does not incorporate a criterion regarding the impact noise of floors and slabs.

The MINEDUC acoustic design criteria neither establish a differentiation according to the students' educational level, that is, preschool, primary and secondary school classrooms have the same acoustics. However, the evidence shows that the children under 13 years of age are neurologically more susceptible to be affected by noise and reverberation and, therefore, they are considered a risk population in classrooms with poor acoustics. Consequently, international standards establish different acoustic criteria for primary versus secondary school classrooms. These differences are usually expressed in terms of the background noise level, the reverberation time, or both.

In the era of inclusion, the acoustic design criteria for educational environments of the Ministry of Education do not consider inclusive classrooms. They do not consider acoustic design criteria for classrooms aimed at students with hearing or language impairments. When talking about inclusive learning environments, it should be considered that the risk population due to the exposure to poor acoustics in the classroom also includes children with some level of hearing loss, children who suffer articulation disorders (palatal fissure, apraxia), language disorders (aphasia, specific language impairment) or auditory processing disorder, as well as immigrant students learning in a non-native language (Anderson 2008).

When discussing the need for acoustic quality standards in learning environments of the country, one of the most recurrent opposing arguments is the economic cost of implementing these measures. Not only concerning the construction of new educational institutions, but also the renovation of schools already built. In this respect, the OECD is clear and recommends to invest on quality learning environments, since they improve the academic achievement of the students, which leads to GDP increases in the long term.

4. Conclusions

Given that verbal communication is the primary means to learn in the schools, acoustics has become one of the most important architectural attributes in the design of learning environments. Classroom acoustics gains more relevance when considering that children and youngsters under 20 years old have not reached a full auditory brain development. Children educated in classrooms with bad acoustics –noisy or reverberant classrooms, or with little speech intelligibility- learn less and show a lower academic achievement and cognitive development. Negative effects start showing at 4 years of age, and children up to 13 years old are regarded as a risk population in the face of bad classroom acoustics.

In 1999, the Chilean Ministry of Education made recommendations for architectural design of learning environments; however, it was not until 2015 that acoustic criteria were incorporated in the design of educational infrastructure in the country. Although it is a step in the right direction, the current regulation suffers the lack of some important definitions. Among the most significant, the absence of a criterion referring to the maximum level of background noise inside the classrooms should be highlighted. This is especially troublesome if we consider that 70.63% of the schools in Santiago are exposed to such urban noise levels that it is unfeasible to apply the MINEDUC's acoustic criterion. Other important limitations of the regulation include the absence of acoustic design criteria for preschools, the lack of differentiation of acoustic criteria based on the educational level, and the inexistence of criteria aimed at special education classrooms.

As matters now stand in the search for strategies that allow improving the quality of education in our country, it seems advisable to turn to methods of proven effectiveness, such as building quality learning environments. The investment on school infrastructure can enhance the students' academic achievement, which is transformed into economic growth in the long term. Therefore, it is imperative to rely on public policies that define and supervise adequate, modern and inclusive acoustic performance criteria for the design and construction of educational infrastructure in our country.

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