Creative Education, 2018, 9, 2819-2842
http://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

Acoustic-Structural Influences in Brazilian Education

André Vieira Sonoda, Ana Paula Furtado Soares Pontes

Department of Digital Media, Universidade Federal da Paraíba, João Pessoa, Brazil
Email: sonodadoc@gmail.com

How to cite this paper: Sonoda, A. V., & Pontes, A. P. F. S. (2018). Acoustic-Structural Influences in Brazilian Education. *Creative Education, 9,* 2819-2842.
https://doi.org/10.4236/ce.2018.916212

Received: June 28, 2018
Accepted: December 17, 2018
Published: December 20, 2018

Abstract

It presents partial results of a research project about acoustic-structural influences on Brazilian education based in the analysis of Campus I of the Federal University of Paraíba (UFPB) in 2016 beyond literature related to the theme in other Brazilian states. It pretends to call attention to the fact that diverse inappropriate acoustic-structural aspect of classrooms and academic environments can generate damage to the educational process and health. The methodology is based on bibliographic analyses and acoustic evaluate of academic environments. The results suggest pedagogical losses in the sense of insufficient school development, possibilities of health problems besides irreparable hearing loss, aspects incompatibles with cognitive activities, improvement of the quality of life and educational development. It is concluded that the architectural and acoustic-structural aspects of projects related to classrooms and school structures need alterations that permit better quality of life for professionals and students, appropriated conditions for the educational process and improvement of academic performance.

Keywords

Acoustic-Structural Influences, Pedagogical Losses, Brazilian Education

1. Introduction

Diverse societies across the globe have faced problems related to acoustics in different aspects. Solutions to problems of this nature have been objects of research and essential aspects for technological improvements in diverse continents since the beginning of the 20th century, a fact observable mainly by the emergency of institutions dedicated to the subject, such as the *Acoustical Society of America* (ASA)[1], *International Commission for Acoustics* (ICA)[2], *Deutsche*

[1]http://acousticalsociety.org/content/brief-history-acoustical-society-america
[2]http://www.icacommission.org/introduction.html

Gesellschaft für Akustik (DEGA)[3], *Société Française d'Acoustique* (SFA)[4], *European Acoustics Association* (EAA)[5], *Institute of Acoustics* (IoA)[6], *Brazilian Society of Acoustic* (SOBRAC)[7], etc.

By the end of 1970s, Broner (1978), in a publication in the *Journal of Sound and Vibration,* had already addressed the issue of low frequency noise (LFN)[8] as a topic of growing interest in the society at the time. Currently, studies show that low frequency can influence physical and mental health in varied ways (Ferreira et al., 2006; Pedersen, 2008; Broner, 2011; Nohama & Silvério-Lopes, 2009; Venslauskas, Ostasevicius, & Vilkinis, 2017). In fact, researches with infrasound, ultrasounds and low frequency sounds are recent in several aspects. For Pedersen (2008) "[...] The human hearing at low-frequencies […] is a research area, where the knowledge is still quite limited." (Pedersen, 2008: p. 13). In Rachel's conception (2006, p. 443):

> Although ultrasonics has been employed for most of the twentieth century, the tempo of new and improved applications has reached virtually explosive proportions only in the past few years (Raichel, 2006: p. 443).

Based on an initial bibliographic review covering publications between the 20th and 21th centuries, it is possible to perceive diverse allusions to the influence of acoustic over the man.

In 2006, the *World Health Organization* (WHO) pointed the noise as one of the major causes of insomnia and deafness (Delfina, 2013: p. 1). In Brazil, in 2007, a thesis analysed the relations of the silence and attention with the auditory perception, concluding that the factors studied, in fact, exert an influence on the human auditory capability (Knobel, 2007). In Portugal, in 2013, a thesis addressed the noise in schools, concluding that:

> Were determined values of sound pressure levels [...] between 75 dB (A) and 84 dB (A) on most situations studied and about 27% of situations the values were above 85 dB (A). According to WHO, these results suggests that existing noise [...] can contribute to increase of aggression and school failure, as well as cause psycho-physiological problems. (Pereira Branco, 2013: p. 69)

Studies about hearing loss suggest that recurrent exposures to noise with high SPL can reduce hearing capability in musicians (Gonçalves et al., 2009; Amorim et al., 2008; Martins et al., 2008). Therefore, it is possible to conclude that acoustic influences on the human health really are not recent and represents urgent and worrying issues. On the other hand, when we consider influences on the educational process, it is easy to see that part of the problem arises from the de-

[3] *German Acoustical Society* (DEGA) (See: https://www.dega-akustik.de).
[4] *French Acoustical Society* (SFA) (See: http://sfa.asso.fr/fr/accueil).
[5] https://euracoustics.org
[6] http://www.ioa.org.uk
[7] http://acustica.org.br
[8] Low Frequency Noise - LFN (Broner, 1978).

sign of the structures, with main emphasis on classrooms and teaching environments (Bastos, Cardoso, & De Melo, 2010; Pereira et al., 2004; Guidini et al., 2012). Moreover, from the architecture point of view, still does not seem to exist a scientific consensus of acoustic-structural factors that influences directly or indirectly the pedagogical and intellectual practices.

In Brazil, structural characteristics of learning Institutions, in many aspects, derive from architectural conceptions focused on the best use of variables (Gonçalves & Duarte, 2006; Nascimento, 2009; Carvalho, 2011), however, the acoustic results from these structures may not contribute adequately for a full educational development, specially when reverberation times, noise sources, sound pressure levels, finishing materials, classroom dimensions and formats, among other aspects, are unsuitable for the type of activity for which were designed (Bastos, Cardoso, & De Melo, 2010; Batista et al., 2010; Dreossi & Momensohn-Santos, 2005; Gonçalves, Silva, & Coutinho, 2009; Mendes et al., 2016).

Aiming at an initial survey of the acoustic characteristics of *Campus I of the Federal University of Paraíba* (UFPB) the project *Analyses of the Sound Pressure Levels on the Campus I of UFPB* was approved in the Department of Digital Media (DEMID/UFPB) and implemented in 2016 as the first step of the research. In this, decibelimeters were used to evaluate sound pressure levels of 07 (seven) pedagogical environments of the Institution over a period of 08 (eight) months. Based on the initial results, was perceived a worrying context related to the high SPL[9] in all analysed sites (Sonoda, 2016). In this sense, bibliographies concerning the subject suggest that the levels measured can induce negative impacts on the intellectual practices, auditory systems, aggressiveness rates, academic performance, quality of life, communication process, damages to physical and mental health, etc. (Gonçalves et al., 2009; Pereira Branco, 2013; Santos & Santos, 2000), problems probable in a short time and directly related to the educational process. At the same time, a diversity of bibliographies demonstrates that the acoustic contexts of the educational institutions in Brazil are, in fact, inadequate for their respective main proposes (Pereira et al., 2004; Bastos, Cardoso, & De Melo, 2010; Almeida Filho et al., 2012).

The second stage of the research will be characterized by the acoustic analysis of classroom of Campus I of UFPB, aiming at the constitution of a situational context as complete as possible within the scope of acoustic-structural influence over the educational process. The evaluate will employ *software*[10] that allows analyses of sound-spectrum with *Fourier Fast Transform (FFT)* (Huang & Benesty, 2004: p. 142; McLoughlin, 2009: p. 135; Kester et al., 2005: pp. 173-174) and RTA[11]; reverberation time (RT_{60}); sound pressure level (SPL); equivalent pressure (L_{eq}); signal-to-noise relation[12] (McLoughlin, 2009: p. 50), etc. On the other hand, will be evaluated acoustic inadequacies related to the shapes, dimen-

[9] *Sound Pressure Level* (Howard & Angus, 2001: pp. 17-20).
[10] *Electroacoustics Toolbox da Faber Acoustical* (Ver: http://www.faberacoustical.com/apps/mac/).
[11] *Real Time Analyzer* (RTA).
[12] *Signal Noise Relation* (SNR).

sions and materials, such as the parallel structures responsible for the generation of stationary waves (Toole, 2008: p. 208; Everest, 2001: pp. 400-413); improper reflection coefficients; sources of high internal and external noise; phase problems, currently solved with quadratic residue diffusers (QRD)[13] (Everest, 2001: p. 298), among others.

Based on personal experience with acoustic projects, pedagogical practice, results of the first stage of the research (Sonoda, 2016) and bibliographic analysis, the initial hypothesis holds that the acoustic-structural influences of classrooms and educational environments over the pedagogical process are responsible for insufficient academic improvements in Brazilian institutions, with special emphasis on the North and Northeast Regions of the country. This notion considers, fundamentally, the most representative characteristics of architectural projects of classrooms, such as reverberation times (RT_{60}), noise levels unacceptably accentuated, parallel structures, flat surfaces and high density finishes, aspects responsible for low indexes of speech intelligibility, standing waves, reduced coefficients of diffusion and refraction and high reflexion coefficients (Gonçalves, Silva, & Coutinho, 2009; Guidini et al., 2012; Dreossi & Momensohn-Santos, 2005; Levandoski, 2013; Dos Santos, 2012). These aspects are, undoubtedly, opposed to the pedagogical success and thus, they must be considered simultaneously to the social and human ones, allowing more precise findings about the acoustic influences on the pedagogical process.

Considering the exposed, a logarithmic mathematical model that contemplates acoustic-structural, architectural and human variables capable of influencing the educational process will be developed. The choice for the logarithmic characteristic of this model was due to the treatment of variables fundamentally related to the human senses, better represented mathematically by logarithmic or exponential functions, especially with emphasis on the logarithms of base 10 (ten) (Everest, 2001: pp. 28-30). Further, considering the prospect of a possible solution for the noise as main problem in this context, it is intended to develop a prototype of sound pressure control in a confined environment (classroom) by polarity inversion and phase cancellation (Kuttruff, 2000: p. 191; Watkinson, 1998: p. 99; McLoughlin, 2009: p. 63; Huang & Benesty, 2004: pp. 91-111).

Therefore, it is expected that the study will allow the identification and detailed analysis of the acoustic-structural characteristics of classrooms and pedagogical environments capable of undermining the educational process, allowing the creation of the mentioned mathematical model that allows architectural projects more adequate to the specific needs of education. It should also be noted that the project considers the whole audible sound spectrum, the frequency range between 20 Hz and 20 kHz with amplitude variations between 1 W/m^2 (120 dBA) and 10^{-12} W/m^2 (0 dBA), or 20 μPa in terms of pressure (Everest, 2001: pp. 28-33; Talbot-Smith, 1999: pp. 1.38-1.43). With the conclusion, it is expected to demonstrate a situational picture of acoustic context of the Campus

[13] *Quadratic-Residue Diffusors* (QRD).

I of UFPB, revealing precisely the influences of this amalgam of acoustic-structural, social and human variables on the educational process in the studied universe.

2. The Justification

The relevance of this research is related, mainly, with the determination of acoustic-structural influences on the educational process. However, the collection of information about the acoustic context of Campus I of UFPB is also relevant for generating accurate data about possible negative influences on the educational process. Considering the main emphasis of that research related to influences of acoustic-structural characteristics on the educational process and the academic performance, information that enables improvements on the pedagogical and work conditions or can generate more coherent architectural conceptions for projects with educational purposes are essential while results.

Despite this, it is possible highlight other aspects that are important to justify the proposal. Among them, the involvement of undergraduate students in scientific research in the Institutional Programs of Scientific Initiation (PIBIC/PIVIC/UFPB), resulting in greater integration between teaching, research and extension, as well as theoretic-practical development since the first levels in undergraduate courses, aspect also foreseen in Political Pedagogical Projects (PPP) with positive influences in the intellectual and scientific production of the Departments involved.

The detailed comprehension of the acoustic context of the UFPB also represents important information on the field of public health. By enabling preventive measures against irreparable hearing loss or damage for physical and mental health among professionals and students, there is an increase in quality of life and reduction of costs with human resources. On the other hand, when we assume that acoustic-structural contexts of the education institutions may not be contributing adequately to pedagogical success, we face a problem of national or even global proportions that demands urgent and definitive solutions, especially, if the problem coexist at different educational levels as the bibliography suggests. Despite its complexity, understanding this framework seems essential urgent to justify the study and the search for effective solutions which will undoubtedly benefit future generations.

It is important to point out that similar initiatives about Campus I of UFPB do not seem to exist until the present moment. In addition, the originality of the proposal is guaranteed by the use of techniques and principles characteristic of acoustic projects of musical production studios; analysis and concepts arising from audio engineering, therefore, unusual in construction; the use of specific tools that enable the evaluation of the extremes of audible part of the sound spectrum, such as flat-response omnidirectional electrostatic microphones, infrasonic and ultrasonic spectrum analysers, digital triaxial accelerometers (Bouten et al., 1997) for analysis of the magnitudes of mechanical oscillations of structures as well as signal generators focused on the analytical needs that are parts of the proposal.

While two last aspects of innovation, it is important to note, first, the consideration of phenomena in whole audible sound spectrum for humans (frequencies between 20 Hz and 20 kHz). Although this orientation may configure a deviation from the frequently used approach in the area, which to prioritizes the range between 125 Hz and 8 kHz (Bastos, Cardoso, & De Melo, 2010), high frequencies may be audible only by children[14] (Siewe, 2007: p. 2140.3), while low frequencies can induce psychophysiological sensations that oppose pedagogical and intellectual activities (Medeiros, 1999: p. 12). And, second, the prototype of SPL control in classrooms by inversion of polarity and phase cancellation (Kuttruff, 2000: p. 191; Watkinson, 1998: p. 99; McLoughlin, 2009: p. 63; Huang & Benesty, 2004: pp. 91-111) is a technology able to definitively solve the noise issue as the main element of acoustic influence in educational contexts around the world.

These results will be important as methodological-conceptual orientations for architectural projects of structures with pedagogical purposes, beyond to the whole area of acoustics. On the other hand, a prototype of sound pressure control that solves the noise problem in the classroom will certainly influence all Brazilian or even global education, inducing a substantial increase in the academic performance and quality of life of professionals and students.

3. The Project Objectives

The main objective of this research is the determination of acoustic-structural influences in Brazilian education, through the evaluation of classrooms and pedagogical environments characteristics of the Campus I of UFPB besides bibliographic analysis about this theme in others Brazilian States. Based on resulted data it is expected to elaborate a logarithmic mathematical model that assist architectural projects specific for education beyond the development of a prototype for sound pressure control in confined space by inversion of polarity and phase cancellation (Kuttruff, 2000: p. 191; Watkinson, 1998: p. 99; McLoughlin, 2009: p. 63; Huang & Benesty, 2004: pp. 91-111).

The determination of these influences in Brazilian education can contribute to important changes on the architectural conceptions about buildings designed for cognitive and pedagogical practices resulting in essential improvements on the school productivity and health of professionals and students. In this sense, the creation of a mathematical model seems important as subsidy for that improvement on architectural practices. On the other hand, the prototype for sound pressure control in confined space has potential for solves the acoustic problem of noise on pedagogical environments. Finally, it is expected to demonstrate in what acoustic aspects the classrooms of the Campus I of UFPB are improper to the teaching and especially why they are.

To reach this complex objective will permit acoustic solutions for architecture

[14]http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2418/T-2140web.pdf

projects focused on education, increasing productivity on that environments. On the other hand, the development of the prototype of sound pressure control for classrooms will be essential for improvement of the Brazilian education and the technological advancement of the acoustics in a global context, specifically, considering the elevated cost of current solutions to the noise problem.

4. Theoretical Foundations

This research contemplates three central concepts. The acoustic-structural influences on pedagogical processes, the notion of polarity inversion for phase cancellation and the theory of mathematical modeling. On the other hand, despite the exuberance of publications about the relationships between acoustics, human hearing and pedagogical processes, specific contributions about the context of UFPB in this theme was not found.

The acoustical influence on the pedagogical process is a factor that opposes to the development of cognitive practices and education process in general form. On the other hand, may to contribute for physical and psycho-physiological health problems. In this sense, acoustic solutions related to education process have potential for reduce that negative impact besides increase the efficiency on this area. Beyond this, the notions of polarity inversion for the phase cancellation (Kuttruff, 2000: p. 191; Watkinson, 1998: p. 99; McLoughlin, 2009: p. 63; Huang & Benesty, 2004: pp. 91-111) and the use of mathematical models (Pippa, 2014; Marion & Lawson, 2008; Ramos, 2015; Rangu, 2007; COMAP, 2012[15]; Kelly, 2007; Sodré, 2007), respectively related with the prototype for noise control in classrooms and techniques improvement for architectural projects with educational finalities, represent new applications of technologies in contemporary interdisciplinary areas with conditions to promote important theoretical development and advance on practices of architectural project elaboration, construction for specific finalities and acoustic control.

In this sense, publications about acoustic damage to the auditory system, classroom acoustic analysis and noise pollution represent important part of the references available for this work (Bastos, Cardoso, & De Melo, 2010; Pereira et al., 2004; Guidini et al., 2012; Almeida Filho et al., 2012; Oiticica, Alvino, & Da Silva, 2006; Batista et al., 2010; Dreossi & Momensohn-Santos, 2005; Fernandes, 2006; Levandoski, 2013; Gonçalves, Da Silva, & Coutinho, 2009; Gonçalves et al., 2006[16]; Dos Santos, 2012; Tavares, 2016; Pereira Branco, 2013; Mendes et al., 2016; Rodrigues, 2010; Moscati, 2013; Bistafa, 2004; Amorim & Licarião, 2005; Amorim et al., 2008; Martins et al., 2008; Sonoda, 2016; Lacerda et al., 2005; Taxini & Guida, 2008; Da Paz, Ferreira, & Zannin, 2005; Crosato et al., 2007; Howard & Angus, 2001; Beranek, 1969; Fahy & Walker, 2004; Everest, 2001; Valle, 2009; Borges, 2009; Takahashi & Bertoli, 2012; Kuttruff, 2000; Delfina,

[15] *TEACHERS COLLEGE COLUMBIA UNIVERSITY. Mathematical Modeling Handbook. COMAP*, 2012.

[16] http://www.scielo.br/scielo.php?script=sci_nlinks&ref=000116&pid=S2179-64912012000300008000 23&lng=en

2013). About the concept of polarity inversion for the phase cancellation some publications are more representative, however, there are only rare references to applications in the sense proposed here (Ballou, 2009: p. 57; Gibson, 1997: p. 67; Howard & Angus, 2001: p. 55; Beranek, 1969: p. 45; Fahy & Walker, 2004: p. 301; Kahrs & Brandenburg, 2002: p. 116; Talbot-Smith, 1999: p. 2.80; Everest, 2001: p. 367; Kuttruff, 2000: p. 191; Watkinson, 1998: p. 99). About the theory of mathematical modeling the literature found was concentrated on the concept in general form, although some publications contemplates the logarithmic and exponential functions (Pippa, 2014; Marion & Lawson, 2008; Ramos, 2015; Rangu, 2007; COMAP, 2012[17]; Kelly, 2007; Sodré, 2007). Seeking, therefore, a detailed analysis of the references found, a briefly summary of these works is presented below.

The article "numerical and experimental analysis of the acoustic parameters of a classroom of the Federal University of Pará" (Bastos, Cardoso, & De Melo, 2010) presents an acoustic analysis of the classroom, based on ISO 3382[18]. It employs the software DIRAC 4.0 and ODEON 9.2 to evaluate reverb time (RT), early decay time (EDT), definition (D_{50}), fast speech transmission rate (RaSTI) between 125Hz and 8kHz, and simulates the conditions of the environment with different materials. The numerical and experimental results indicated that the model can represents the environment, allowing simulations with varied materials and audiences. It alerts to the importance of measurements in the presence of the audience to better representation of the use of the room (Bastos, Cardoso & De Melo, 2010).

The article "acoustic conditions analysis in an acclimatized classroom environment" (Pereira et al., 2004) analyses the acoustic comfort, evaluating if the indices satisfy the Standard 10152/ABNT (NB 95), by means of measurements of acoustic variables and perception of intelligibility of speech by students. In this case, acoustic differences were found in relation to the standards. However, the speech discrimination index (IDF) was within the established values. The signal-to-noise relation was 8 dB, standing lower than the value suggested in the Standard which is 10 dB for a good understanding of speech. The results of the subjective test indicated lower IDF values for the last queues (close to the air conditioner), suggesting low speech intelligibility at these sites. In the other points of the room, the average was above 90%, indicating good intelligibility. The reverberation time exceeds that established by the Technical Committee on Architectural Acoustics of the ASA[19], suggesting low acoustic quality, besides possible negative influences in the teaching. The authors conclude that the room presents poor acoustics with possibility of damages to the teaching, although the questionnaire is contrary (Pereira et al., 2004).

The article "correlations between ambient noise in the classroom and teach-

[17] *TEACHERS COLLEGE COLUMBIA UNIVERSITY. Mathematical Modeling Handbook. COMAP*, 2012.

[18] https://www.iso.org/obp/ui/#iso:std:iso:3382:-3:ed-1:v1:en

[19] *Acoustical Society of America* (ASA).

er's voice" (Guidini et al., 2012) analyses correlations between environmental noise inside the classroom, voice intensity and presence of voice alteration in teachers, applying measurements in ten rooms of municipal primary schools. The intensity of teachers' voices was measured during teaching activity using GRBASI scale. The results were correlated, indicating that ambient noise in the classroom, without the presence of children, varies between 40 dB (A) and 51 dB (A) and, in the presence of these, between 45 dB (A) and 65 dB (A). The index of altered voices among teachers was 70% in the general degree (G) and 90% with tension in voice (S), varying between discrete and moderate degrees. There was variation between 52 dB (A) and 68 dB (A) in the intensity of voice among teachers, reaching 7.48 dB (A) above the ambient noise level. The conclusion was that the ambient noise in the classroom is high and it is related to the teacher vocal intensity in the presence of the children during the classes. However, despite the high occurrence of altered voices, it was not possible to correlate them with the environmental noise level (Guidini et al., 2012).

The article "intensity of noise produced in the classroom and analysis of acoustic emissions in schoolchildren" (Almeida Filho et al., 2012) evaluated the exposure of students to noises of harmful intensity to the cochlea, seeking to define the profile of the students and to demonstrate possible changes on cochlear activity after one-day exposure to school noise. It used questionnaires to evaluate a previous cochlear lesion; assessment of cochlear function through the analysis of acoustic emissions before and after school, as well as noise measurement within classrooms and at recreation sites during breaks. It was found that 57.1% of the students demonstrate hearing loss before class, with 07 (seven) of them presenting worsening at the end. The noise exceeded the recommended thresholds in the three rooms and the highest number of students who presented worsening belonged to the room with the highest noise level. The noise produced during the intervals was also considered excessive. It was concluded that, in this school, the noise exceeds the limit. 42.85% of the students who presented worsening have insufficient school performance and 25% of the students presented worsening after exposure to the noise of a school day (Almeida Filho et al., 2012).

The article "interference of the ceiling fans in the acoustic quality of classrooms of public schools in the city of Maceió-AL" (Oiticica, Alvino, & Da Silva, 2006) evaluated the noise level in 58 schools, measuring equivalent sound pressure levels (Leq) with and without the use of ceiling fans. For the authors, this artificial climatic mode compromises the acoustic quality of the classrooms, presenting possible interferences in the quality of learning. Noise levels were higher than those recommended by NBR 10152 in classrooms, with values reaching 80 dB (A). The noise level of 95% of the classrooms, without the use of the fans, varied between 60 dB (A) and 70 dB (A) and, with the fans on, 72% of the classrooms had indices above 70 dB (A). It was concluded that the investigated institutions are improper because the ceiling fans preclude acoustic comfort. For the authors, acoustic problems can be avoided in the design and with different provisions of materials. They affirm that the cost of architectural renovation, although high, is reduced when compared to the social ones due to the influence of acoustic deficiencies in the learning (Oiticica, Alvino, & Da Silva, 2006).

The article "the environment that gets sick: environmental conditions of work of the elementary school teacher" (Batista et al., 2010) analyses environmental comfort, evaluating teachers' discourse on working conditions in elementary education in João Pessoa - PB. Employs focal group and discourse of the collective subject. The result reveals unhealthy and inadequate working conditions, which can cause damage to health and professional performance (Batista et al., 2010).

The article "the influence of the acoustic environment on learning" (Dreossi & Momensohn-Santos, 2005) analyses changes in students of a school subject to internal or external noise, noting that the Institution is under the impact of noises that oppose learning in a place where the listening situation should be privileged. It concludes that innumerable variables can interfere in the perception of the speech within a classroom, implying in interferences in the learning. The authors suggest that the speech therapist contribute with knowledge and programs of children's awareness to change habits and behaviours harmful to hearing, as well as researches in the area focused on Brazilian Portuguese, seeking to evidence the interference in our language, in the classroom and on learning. They also argue that professionals involved in audiology and/or speech therapy can help in early childhood education not only as indicators of children with changes, but also by mobilizing the school for adaptations that prioritize speech intelligibility (Dreossi & Momensohn-Santos, 2005).

The article "standardization of acoustic conditions for classrooms" (Fernandes, 2006) suggests conditions for a good learning environment based on ANSI Standard S12.60, which establishes background noise; reverberation time and maximum noise for air conditioners as important acoustic parameters for classrooms. For the author, the values indicated by the standard produce a signal-to-noise relation of more than 15 dB throughout the room and voice intelligibility above 95%. It highlights research results in 32 Brazilian public schools, noting that few meet the standard. It discusses five high schools in the city of Bauru-SP that present noise levels of 64 dB (A), affirming that measurements in classrooms at the University of São Paulo presented noise levels of 50 dB (A). He affirms that classrooms require optimum acoustic conditions and that sufficient research is already in place to ensure the link between teaching efficiency and acoustic conditions, considering that the ANSI S12.60 complies with its objective by requiring adequate room acoustics and considers that the construction market has acoustic insulation materials capable of providing the insulation foreseen, although they do not use them. It highlights, as a critical point of the standard, the noise level required for the air conditioning system, which suggests uses of central systems. For the author, in the United States, adequate acoustics in classrooms will become a market requirement, while in Brazil the process will be more time-consuming, going from the adoption of norms to the demands of society (Fernandes, 2006).

The doctoral thesis "quality of life and acoustical comfort in educational environments" (Levandoski, 2013) analysed two work environments with different acoustic characteristics, verifying if the quality of life and the occupational health of the workers presented divergences. The study analysed 61 teachers of basic education in public education in the city of Curitiba-PR. For the author, no significant differences in quality of life were detected between the teachers of the two schools. The teachers' quality of life and vocal perception are considered satisfactory, without differing significantly between the analysed Institutions. The quality of life among participants presented values higher than the Brazilian average population and similar in comparisons with teachers. The results revealed a sound pressure level within the classroom of 54.9 dB (A) and a reverberation time of 0.8 s for school 01 (acoustic comfort), while school 02 (acoustic discomfort) showed 74.0 dB (A) and 1.7 seconds. It was verified that the teachers use a vocal intensity superior to the tolerable limits for a safe hearing, aggravating the auditory condition of the students. 58.6% of teachers consider high noise in the workplace, in which the intensity of the teacher's voice in a 45-minute class was 87.3 dB (A). The teachers of the comfort school presented higher voice intensity compared to the school of discomfort and it was demonstrated that the number of students per class has a 24.8% effect on the level of vocal intensity of these professionals. For teachers, the major causes of acoustic nuisance come from within the classroom. For the author, the teaching activity could be considered occupational risk profession, due to the intensities of the sound levels in the classroom exceed the recommendations for teaching activities. Therefore, the basic conditions necessary for the health of teachers during the exercise of their profession are not satisfactory. The author concluded that the schools do not present safe sound levels for teachers to carry out their work activities, considering also that the number of students in each classroom contributes significantly to the increase of the vocal intensity of the professional in education. It suggests a revision of normative values and regulations, as well as an analysis of the teaching profession as occupational risk activity not only as a source of noise but also as an emitting source in occasions of educational activities with classes with more than 25 students (Levandoski, 2013).

The article "noise as a compromising agent of teachers' speech intelligibility" (Gonçalves, Da Silva, & Coutinho, 2009) analyses the level of sound pressure in classrooms and their interference in the intelligibility of teachers' speech. With descriptive and exploratory methodology of qualitative and quantitative nature, the research considered comfort/discomfort evaluations; acoustic assessment and vocal performance evaluation. For the authors, some situations force the teacher to be one of the most affected by vocal problems, highlighting the long working day with voice use; overwork; the excessive number of students in the classroom; the indiscipline of the students; inadequate working conditions; poorly designed classrooms; external and internal noise to room; inadequate teacher rooms; lack of information on vocal health in training, etc. 94.6% of teachers stated that it was necessary to increase the tone of voice for speech intelligibility. Sound pressure levels varied between 46.60 dB (A) and 87.90 dB (A) and teacher vocal performance between 49.01 dB (A) and 83.75 dB (A). Only in one room the comfort level was acceptable, with 97.30% of the rooms being outside the standard of NBR 10152 (ABNT, 1987). It was concluded that the low acoustic performance requires greater vocal effort of the teacher, causing speech fatigue. This aspect is due to internal and external sources and the high number of students. As a consequence, the teacher is exposed to pathologies that impact directly his/her performance, with productivity consequences and deviations that affect the city in question (Gonçalves, Da Silva, & Coutinho, 2009).

The article "endemic study of noise and speech intelligibility of teachers: a comparison between two schools" (Gonçalves et al., 2006) evaluated the sound pressure level inside the classrooms of two municipal public schools in the city of João Pessoa (PB), favouring comparisons with constant values in the legislation, besides analyses of the comfort/ discomfort degree and level of interference in speech intelligibility. Were registered 77 dB (A) sound pressure level, higher than 50 dB (A) set at ABNT as acceptable for classrooms. It was concluded that the evaluated schools have high noise levels and do not present acoustic adequacy favourable to the teacher's performance or comfort in relation to their voice intensity or to the teaching-learning process, and are therefore unprepared to minimize the negative effects of noise in terms of comfort, intelligibility of speech and pedagogical activities. It alerts that better vocal performances and learning processes, demand considerations of aspects such as noise and acoustics of classrooms by designers (Gonçalves et al., 2006).

The dissertation "analysis of the influence of acoustic parameters on speech intelligibility: a study in classrooms of municipal schools in João Pessoa" (Dos Santos, 2012) evaluated the acoustic conditions of 119 classrooms, considering Brazilian and international standards. Through the construction of a beta regression model, it was verified to what extent the acoustic parameters of these rooms interfere in the intelligibility of the teachers' speech, noting that the noise level of sources external to the classrooms, background noises, reverberation time and the speech intelligibility indexes are not within the reference values of the applicable standards. The mathematical modelling presented consistency and the variable *reverberation time* was the most representative, demonstrating that it can influence the quality of intelligibility (Dos Santos, 2012).

The conclusion work of undergraduate course "an overview of noise levels for acoustic comfort of VDT[20] teaching environments in areas of Brazilian regions" (Tavares, 2016) evaluated the noise levels of six computer labs with VDT of Technology Center of Higher Education Institutions (HEIs), evaluating equivalent noise levels (L_{eq}), and elaborating a mathematical model for comparing levels between institutions. The compliance of the levels found was assessed on the basis of NBR 10152/1987, ANSI S12.60-2002 and the guidelines of the World

[20]Video Display Terminals (VDT).

Health Organization (WHO). The measurements were carried out according to NBR 10151/2000, between 2014 and 2016, in informatics laboratories of IES of the Northeast, North, South and Southeast regions of Brazil. The descriptive analysis showed that the six environments evaluated presented L_{eq} higher than the values established in the norms and the mathematical model made it possible to corroborate the results obtained. By evaluating the architectural aspects of the laboratories, it was concluded that the high noise levels might be related to the low absorption coefficients of the materials that constitute them (Tavares, 2016).

The dissertation "noise in schools" (Pereira Branco, 2013) identified sound levels between 75 dB (A) and 84 dB (A) in most school situations, revealing that about 27% of the situations presented values above 85 dB (A). The results suggested that noise in schools and canteens evaluated may contribute to increased aggression and school failure, as well as causing psychophysiological problems (Pereira Branco, 2013: p. 69).

The article "teacher's voice: symptoms of discomfort of vocal tract, vocal intensity and noise in the classroom" (Mendes et al., 2016) analysed possible correlations between vocal intensity of 27 elementary school teachers and room noise as well as between vocal intensity and symptoms of discomfort of vocal tract before and after school. It used questionnaires about the teacher's vocal production condition and discomfort of vocal tract scale before and after class. To measure the noise and vocal intensity, a decibel meter was used. It was concluded that the increase in the vocal intensity of the teachers correlates with the high noise levels, observing a correlation between vocal intensity and symptoms of discomfort of vocal tract, most of the symptoms being reported more frequently and intensely after class. The vocal intensity measures are also related to the symptoms of discomfort of vocal tract in pre and post-class situations. It is observed a greater number of symptoms of discomfort after the period of 04 (four) hours of class, having a correlation between this increase and the amplification of vocal intensity (Mendes et al., 2016).

Regarding the references related to the concepts of phase cancellation by inversion of polarity, it is highlight sporadic references in bibliographies with emphasis in the field of audio engineering (Ballou, 2009. p. 57; Gibson, 1997: p. 67; Howard & Angus, 2001: p. 55; Beranek, 1969: p. 45; Fahy & Walker, 2004: p. 301; Kahrs & Brandenburg, 2002: p. 116; Talbot-Smith, 1999: p. 2.80, p. 6.38; Everest, 2001: p. 367; Kuttruff, 2000: p. 191; Watkinson, 1998: p. 99; McLoughlin, 2009: p. 63; Huang & Benesty, 2004: pp. 91-111).

Regarding the references related to mathematical models and logarithms, highlight only those related to the application of this research proposal.

The dissertation "the logarithm function and the calculation ruler" (Pippa, 2014) proposes the use of the ruler of calculation in the teaching of logarithms. It contemplated historical studies, logarithm function, logarithmic functions characterization, association of logarithms with arithmetic and geometric progressions besides the use of a slide ruler (Pippa, 2014).

The book "introduction to mathematical modelling" (Marion & Lawson,

2008) develops a framework that analyses the mathematical model addressing meaning, objectives, classifications, and stages. It addresses the systems of analysis, entering into the propositions, diagrams and choices of equations, besides the dimensions, sensitivity analyses and tests of the models. About the structure, it analyses proposition tests, reasons for predicting errors, parameters and model comparison for the same system, as well as use and predictions with precision estimates. In the last chapter, the model description and the decision of when to use a mathematical model are analysed (Marion & Lawson, 2008).

The book "logarithms: a didactic approach" (Ramos, 2015), addresses logarithms in three ways. The first as an exponent, the second establishing a relation between geometric and arithmetical progressions and the third defining the logarithm as an area under a hyperbola, considered a preamble to differential and integral calculus. A historical approach and analyses of logarithmic and exponential function are presented as the most adequate mathematical models. The main properties of these functions are discussed, with special attention to the e^x function. The final analysis addresses the loss of the initial relevance of the logarithms to increasing the power of arithmetic operations, although they had maintained their prominence in mathematics teaching mainly because their ability to describe mathematically quantities whose rates of variation are proportional to the quantity of these mathematical greatness at a given moment (Ramos, 2015).

The book "mathematical models" (Sodré, 2007) begins with the concepts of mathematical models, addressing the role of the model in scientific research, the aspect of construction of the model, classification of models between mechanistic and empirical, contrasts of different types of models, weak and strong points, ordinary differential equations (ODE), population models and mathematical models (Sodré, 2007).

It is important to emphasize that the publications mentioned allow the development of the research in a satisfactory way. However, in the course of that and during the writing of final report, other works should be contemplated.

5. Theoretical-Methodological Procedures

5.1. Conceptual Apparatus for Foundation

Despite the diversity of bibliographic sources about acoustic influences of classrooms on educational processes, no bibliography on the specific case of *Campus I* of the UFPB has been found, except for the partial results of research previously mentioned (Sonoda, 2016). Thus, the theoretical basis should use the available references related to acoustic influences on educational processes, besides being based on the literature on acoustics and audio engineering. These last ones, will also base the prototype of sound pressure control by polarity inversion and phase cancellation in confined environment.

In the scope of the mathematical model, will be used the sources described in the theoretical framework in addition to others materials related to this thematic, since a diversity of scientific publications is available since the mid-seventeenth century regarding the logarithmic function as result of the Napier works (Pippa, 2004; Ramos, 2015; Taylor & Thompson, 2008) and since the end of the 19th century about the use of the mathematical models[21], implemented in Brazilian education at the end of the 20th century (Magnus, 2014[22]). Further, all analyses will be guided by Brazilian and international standards.

5.2. Research Techniques and Analytical Tools

The techniques to be used in the acoustic analysis of classrooms will include since bibliographical analysis to verification of architectural structure related to the shapes, dimensions, finishing materials, mobile structures, etc. Additional analyses of amplitudes and frequencies of building structures will be included as an initial consideration for the analysis of infrasound noise due the structural vibrations. For this, digital triaxial accelerometers (Bouten et al., 1997), seismographs and the Seismac 2.0 software from Suitable Systems will be used for triaxial seismic analysis of frequencies and amplitudes of vibrations.

For the definition of acoustic-structural influences on the educational process, will be used tests suggested in national and international standards; questionnaires with students and teachers, as well as evaluation of school performance based on student academic records.

Regarding acoustic evaluations, the analyses will make use of the software Electro Acoustics Toolbox from Faber Acoustical[23], enabling sound spectrum analysis (FFT/RTA); reverberation time (RT_{60}); sound pressure levels (L_p) in classrooms; equivalent sound pressure levels (L_{eq}); statistical levels (L_{90}, L_{10}), speech interference level (SIL); speech transmission index (STI); levels of voice intelligibility; speech definition (D_{50}); clarity (C_{80}); signal-to-noise relation (SNR) (McLoughlin, 2009: p. 50); standing waves (Toole, 2008: p. 208; Everest, 2001: pp. 400-413); internal and external noise sources; background noise; early decay time (EDT); level of acoustic comfort; speech discrimination index; ratio between direct and reverberant sound (RDR); number of students per class; internal noise of the room with air conditioning system on and off, as well as analyses with and without students being present.

For the development of the prototype of reduction of sound intensity in confined environment by polarity inversion and phase cancellation, will be used omnidirectional flat response microphone (15 Hz - 45 kHz); flat response audio monitor (20 Hz - 20 kHz); digital mixer; decibelimeter; laser tape measure; sound spectrum analyser; colourful sonogram; oscilloscope and accessories. This technology possibly will require patent registration and should require some level of control in terms of public disclosure during testing and development.

For the elaboration of the logarithmic mathematical model, will be initially defined the acoustic, structural, social and human variables that can to influence

[21]https://www.maths.ox.ac.uk/about-us/departmental-art/history
[22]http://www.ufjf.br/ebrapem2015/files/2015/10/gd10_maria_magnus.pdf
[23]http://www.faberacoustical.com/apps/mac/

the educational process. Subsequently, scales of logarithmic variations with weighting of each variable will be attributed according to their degree of influence on the educational process and application of correction factor for sum of decibel indices. All measurements will be based on national and international regulatory standards, as well as parameters defined in the SI (Taylor & Thompson, 2008). Finally, techniques and procedures involving qualitative and quantitative practices (Bauer & Gaskell, 2002; Queiroz, 2006), besides structured interviews and questionnaires (Duarte, 2002), sampling, audio recording, photography, etc. should be included in favour of better conditions of evaluation and analysis of the studied object.

6. Fieldwork

Over a period of 08 (eight) months were used two types of decibelimeters[24] for evaluated the 07 (seven) convivial places in Campus I of the UFPB in terms of sound pressure levels (SPL). Before the start of measurements, these devices were tested in the audio-visual studio of the Department of Digital Media of UFPB for verify possible difference in values in their SPL analyses. Using even levels of sound pressure, white noise (Everest, 2001: pp. 111-112) and the identical spatial positioning of the decibelimeters in the room, differences were considered negligible in the SPL values showed by the two devices[25]. After this confirmation, the SPL measurement process was started at the seven places, which were chosen such as sample because they were considered noisy on the student conception. In order to better comprehension of the risks inherent to the evaluated places, it is worth pointing out two reference SPL values, that is, 65 dB (A) and 85 dB (A) respectively. The first one being capable of generating impairments to intellectual and cognitive activities, besides difficult communication and concentration (Zajarkiewicch, 2010: p. 17) and the latter, being capable of promote irreparable hearing losses (Gonçalves et al., 2009). Considering these levels as initial reference values, it is possible to analyse the fieldwork results.

The three first places evaluated were the Center of Experiences (CV) of UFPB, the entrance hall of the Department of Digital Media of UFPB (DEMID/UFPB) and another open space of food commerce known as Vascão. The CV concentrates diverse food establishments in an environment of convivial student in open space. At this site, 16 (sixteen) measurements were performed between February and May 2016 with minimum and maximum SPL values of respectively 63 dB (A) and 90 dB (A) besides arithmetic mean of 73.5 dB (A). At this location, only one of the sixteen measurements was below the reference value of 65 dB (A). In the entrance hall of the Department of Digital Media, a place considered confined environment that presents high SPL in intervals between classes in consequences of the concentration of students, fifteen measurements were performed between March and May 2016, with minimum and maximum SPL

[24] *Minipa MSL 1325-A* and *Instrutherm DEC*-490.

[25] Diferenças da ordem de 0.2 dB (A), consideradas desprezíveis para a aplicação proposta no projeto de pesquisa.

values of respectively 67 dB (A) and 85 dB (A), besides arithmetic mean of 74.4 dB (A). In this case, no measurement was classified as inferior of the reference level of 65 dB (A). In the case of Vascão, also characterized by food commerce establishments and considered to be noisy due to the high concentrating of people, only 03 (three) measurements were performed in April/2016, with minimum and maximum values of 75.5 dB (A) and 89 dB (A) with an arithmetic mean of 83 dB (A) and all values above the reference threshold of 65 dB (A).

Others three places evaluated were the University Restaurant (RU), the Kitchen of the University Residence and the Praça da Alegria (Square of the Joy). In the RU, considered noisy by students and servers, 22 (twenty two) measurements were performed between April and June 2016, presenting minimum and maximum SPL values of respectively 74 dB (A) and 99.3 dB (A) with arithmetic mean of 82.5 dB (A). In the Kitchen of the University Residence 20 (twenty) measurements were performed between April and May 2016, presenting SPL values of 74.7 dB (A) and 87.2 dB (A) with arithmetic mean of 79.7 dB (A) and in the case of the Square of the Joy, located on the Centro de Ciências Humanas, Letras e Artes (Center of Human Sciences, Letters and Arts), 04 (four) measurements were performed between April and May 2016. The minimum and maximum SPL values were, respectively, 68 dB (A) and 81.1 dB (A) with arithmetic mean of 77.2 dB (A). The School of Basic Education of the UFPB (EEBAS/UFPB) was the sixth location evaluated, however, was presented here such as the last one due your special characteristics. At this site the 11 (eleven) measurements were performed between April and September 2016, presenting one of the most worrying contexts among those evaluated. The minimum and maximum SPL values were, respectively, 73 dB (A) and 102.3 dB (A) with arithmetic mean of 86.8 dB (A).

7. School of Basic Education of UFPB (EEBAS/UFPB)

The performed evaluation on the Campus I of the UFPB revelled a critical context of negative influences on the educational process and, despite worrying cases such as the University Restaurant, the School of Basic Education of UFPB (EEBAS/UFPB) have a superior harmful potential due to the various aspects surprising and worrying. The possibility of diverse health problems and irreparable auditory loss on the early years of education process, the same risk for the health and the auditory system of the school employees and professors besides the possibility of compromising human cognitive performance, with impairments to the concentration and memory as a consequence of exposure to the high levels of SPL.

The SPL measurements at the School of Basic Education (EEBAS/UFPB) was carried out in the physical space for children's recreational activities between 05 (five) and 07 (seven) years of age, at the time of the interval of the afternoon classes and under the supervision of support professionals. The reached indexes are worrisome, basically, because the SPL variations between 73 dB (A) and 102.3 dB (A) or even the arithmetic mean of 86.8 dB (A) besides inadmissible due the relation with the child education, suggests that auditory losses besides health and cognitive problems at this school represent a diary process for students, professors and employees. In the covered area where the SPL evaluation was carried out there were an average of 50 (fifty) children among play and sound of ambient music. The games involve an intense movement and energy expenditure with the exploration of the environment and interaction among children in free form with displacement of these throughout the external area (schoolyard), therefore, the students did not only remain in the area where the measurement was performed. The SPL registered were associated with various noises, involving screams of children, songs produced by the school´s sound system and conversations among students, professors and employees, which have to raising the amplitude of their voices to make themselves heard. The elevated levels of noise in this environment, considered sounds without harmony which to cause unpleasant sensation (Freitas, 2008), generated auditory discomfort in the team members during the little time period of SPL measurements.

In this place the SPL exceed the levels set in Article 280 (two hundred and eighty) of the normative instruction INSS/ PRES N˚77 of 21 of January 2015, which emphasizes that occupational exposure to noise exceeding 80 dB (A), 85 dB (A) or 90 dB (A) have to be characterized as activity performed under special conditions. In this sense, noise levels recorded in the School of Basic Education (EEBAS/UFPB) playground may cause temporary and/or permanent hearing damage, tinnitus, sound intolerance, stress, insomnia, tachycardia, dizziness, fatigue and sleep disorders. In addition to these health problems, considering the school context, it is important to highlight the possibility of compromising children's cognitive performance, with impairments to their concentration and memory as a consequence of exposure to high levels of SPL.

In the later stage of the project SPL measurements will be carried out in the classroom, as well as acoustic analysis and interference evaluation of external sounds, aspects that may reveal if these SPL analysed in the interval between classes of the school can influence, to some extent, the classroom environment of others classes that are studying at these times. From these data, it will be possible to define more specific repercussions in the process of teaching learning and in the work and health of the teacher.

8. Results and Conclusions

Problems related to acoustics have been common in contemporary society since the last decades of the twentieth century (Broner, 1978). In the educational context, the main problems in this sense are related to noise with high levels of sound pressure, which may cause damage to the concentration (Medeiros, 1999: p. 23), generating stress (Lacerda, Morata, & Fiorini, 2001), reducing productivity and impairment of communication and learning (Zajarkiewicch, 2010: p. 17), besides generating irreparable hearing loss (Conselho Regional de Fonoaudiologia, 2016).

Through bibliographic analyses and acoustic measurements resulting from a research implemented in *Campus I* of the UFPB in 2016, it was verified that 07 (seven) pedagogical environments of academic conviviality are unfit for intellectual and/or educational activities in acoustic terms (Sonoda, 2016a; Sonoda, 2016b). The mean values of sound pressure levels (SPL) verified using decibelimeters at these sites exceeded the rates considered safe for humans by the World Health Organization (WHO) of 65 dB (A), suggesting also possibilities of irreparable hearing losses, diverse health problems as well as negative influences on intellectual and educational activities. These results suggest characteristics acoustically improper for cognitive and pedagogical development.

With the conclusion of the second part of the research focused on acoustic-structural analysis of classrooms of *Campus I* of the UFPB and the consequent dissemination of the results, it is hoped to demonstrate, on the one hand, that conventional structures of classrooms and educational environments are often inadequate for pedagogical activities and, on the other hand, that architectural projects of educational environments need to have specific acoustic-structural characteristics. It is hoped that the development of a mathematical model can help future designers of educational structures, favouring the creation of pedagogical environments better suited to their respective objectives.

Attention to the acoustic-structural characteristics of Brazilian educational institutions may induce a substantial increase in academic productivity in the medium and long term, as well as to make possible new paradigms for the area of architecture focused on specific purposes as in the case of educational projects. On the other hand, paradigmatic reorientations of this nature may promote reflexes in public policies of health and education for society in general. Finally, the need for urgent and effective political-institutional actions within the scope of the UFPB, as well as the suggestion of verification and measures in the other Brazilian pedagogical institutions is highlighted.

Acknowledgements

It is essential to mention the thanks to Department of Digital Media of the Federal University of Paraíba (DEMID/UFPB) for the technical support for that research project. Besides, that results would not be possible without the commitment of those people. In this sense, special thanks for the students that collaborated on the first part of the investigation do not compensate the magnificent effort realized. The knowledge diffused by this work will be a more adequate retribution for them.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Acoustic Society of America (ASA). https://acousticalsociety.org/

Almeida Filho, N., Filletti, F., Guillaumon, H. R., & Serafini, F. (2012). Intensidade do Ruído Produzido em Sala de Aula e Análise de Emissões acústicas em escolares. *Arquivos Internacionais de Otorrinolaringologia, 16,* 91-95.

Amorim, A., & Licarião, C. (2005). Introdução ao Conforto Ambiental. FEC/ UNICAMP.

Amorim, R. B., Lopes, A. C., Dos Santos, K. T. P., Melo, A. D. P., & Lauris, J. R. P. (2008). Alterações Auditivas da Exposição Ocupacional em Músicos. *ArquivosInternacionais de Otorrinolaringologia, 12,* 377-383.

Ballou, G. (2009). *Electroacoustic Devices: Microphones and Loudspeakers.* Waltham, MA: Focal Press.

Bastos, L. P., Cardoso, H. F. S., & De Melo, G. S. V. (2010). Análise numérica e experimental dos parâmetros acústicos de uma sala de aula da Universidade Federal do Pará. Proceedings of the CONEM - Congresso Nacional de Engenharia Mecânica, BR.

Batista, J. B. V., Carlotto, M. S., Coutinho, A. S., Pereira, D. A. M., & Augusto, L. G. S. (2010). O Ambiente que Adoece: Condições Ambientais de Trabalho do Professor do Ensino Fundamental. *Cadernos Saúde Coletiva, 18,* 234-242.

Bauer, M. W., & Gaskell, G. (2002). *Pesquisa Qualitativa com Texto, Imagem e Som: Um Manual Prático* (5th ed.). Petrópolis, RJ: Vozes.

Beranek, L. (1969). *Acustica* (2nd ed.). Buenos Aires: Editorial Hispano Americana S. A.

Bistafa, S. R. (2004). Difusão Sonora em Salas: Paradigmas do Passado e Estado da Arte. *Proceedings of the Seminário Música, Ciência e Tecnologia: Acústica Musical,* BR, 98-129.

Bouten, C. V. C., Koekkoek, K. T. M., Verduin, M., Kodde, R., & Janssen, J. D. (1997). A Triaxial Accelerometer and Portable Data Processing Unit for the Assessment of Daily Physical Activity. *IEEE Transactions on Biomedical Engineering, 44,* 136-147. https://doi.org/10.1109/10.554760

Broner, N. (1978). The Effects of Low Frequency Noise on People: A Review. *Journal of Sound and Vibration, 58,* 483-500. https://doi.org/10.1016/0022-460X(78)90354-1

Broner, N. (2011). A Simple Outdoor Criterion for Assessment of Low Frequency Noise Emission. *Acoustics Australia, 39,* 7-14.

Carvalho, M. M. Q. (2011). *Alternativas Arquitetônicas para o Aumento da Eficiência no Uso de Energia Elétrica por Edifícios Comerciais.* PhD Thesis, Rio de Janeiro: Universidade Federal do Rio de Janeiro (UFRJ).

Conselho Regional de Fonoaudiologia 2ª Região (2016). *Portaria Nº 19, de 09 de abril de 1998. Secretaria de Segurança e Saúde no Trabalho. Estabelece diretrizes e parâmetros mínimos para a avaliação e o acompanhamento da audição dos trabalhadores, expostos a níveis de pressão sonora elevados.* São Paulo.

Da Paz, E. C., Ferreira, A. M. C., & Zannin, P. H. T. (2005). Estudo Comparativo da Percepção do Ruído Urbano. *Revista de Saúde Pública, 39,* 467-472. https://doi.org/10.1590/S0034-89102005000300019

Delfina, C. (2013). *Soluções Inovadoras para o Conforto Acústico em Ambientes Urbanos.* ComCiência.

Deutsche Gesellschaft für Akustik. https://www.dega-akustik.de

Dos Santos, R. L. S. (2012). *Análise da Influência de Parâmetros Acústicos na Inteligibilidade da Fala: Um Estudo em Salas de Aula de Escolas Municipais de João Pessoa.* Master Dissertation, João Pessoa: Universidade Federal da Paraíba.

Dreossi, R. C. F., & Momensohn-Santos, T. (2005). O Ruído e Sua Interferência Sobre

Estudantes emUma Sala de Aula: Revisão de Literatura. *Pró-Fono R. Atual. Cient., 17,* 251-258. https://doi.org/10.1590/S0104-56872005000200014

Duarte, R. (2002). Pesquisa Qualitativa: Reflexões Sobre o Trabalho de Campo. *Cadernos de Pesquisa, 115,* 139-154. https://doi.org/10.1590/S0100-15742002000100005

European Acoustics Association. *Welcome to the Webportal of the European Acoustics Association*. https://euracoustics.org

Everest, F. A. (2001). *Master Handbook of Acoustics* (4th ed.). New York: McGraw-Hill Companies Inc.

Faber Acoustical (2018). http://www.faberacoustical.com/apps/mac/

Fahy, F., & Walker, J. (2004). *Advanced Applications in Acoustics, Noise and Vibration*. New York: Spon Press. https://doi.org/10.1201/9781315273396

Fernandes, J. C. (2006). Padronização das condições acústicas para salas de aula. In *Proceedings of the XIII SIMPEP*.

Ferreira, J. R., Sousa, J. A., Foreid, P., Antunes, M., Cardoso, S., Alves-Pereira, M., & Castelo Branco, N. (2006). Drive Respiratório Anormal na Doença Vibroacústica. *Revista Portuguesa de Pneumologia, 12,* 369-374. https://doi.org/10.1016/S0873-2159(15)30439-6

Freitas, L. (2008). *Segurança e Saúde do Trabalho*. Lisboa: Edições Sílabo.

Gonçalves, C. G. O., Lacerda, A. B. M., Zocoli, A. M. F., Oliva, F. C., Almeida, S. B., & Iantas, M. R. (2009). Percepção e o Impacto da Música na Audição de Integrantes de Banda Militar. *Revista da Sociedade Brasileira de Fonoaudiologia, 14,* 515-520. https://doi.org/10.1590/S1516-80342009000400015

Gonçalves, J. C. S., & Duarte, D. H. S. (2006). Arquitetura Sustentável: Uma Integração entre Ambiente, Projeto e Tecnologia em Experiências de Pesquisa, Prática e Ensino. *Ambiente Construído, 6,* 51-81.

Gonçalves, V. S. B., Da Silva, L. B., & Coutinho, A. S. (2009). Ruído Como Agente Comprometedor da Inteligibilidade de Fala dos Professores. *Produção, 19,* 466-476.

Gonçalves, V. S. B., Da Silva, L. S., Da Silva, M. C., & Coutinho, A. S. (2006). *Estudo Endêmico do Ruído e da Inteligibilidade de Fala dos Professores: Um Comparativo entre Duas Escolas* (p. 26).

Gonçalves, V. S. B., Sena, L., Carvalho, M., & Da Silva, M. C. (2006). *Ruído ocupacional e a inteligibilidade em salas de aula*. http://www.higieneocupacional.com.br/download/ruido-valeria.pdf

Guidini, R. F., Bertoncello, F., Zanchetta, S., & Dragone, M. L. S. (2012). Correlações entre Ruído Ambiental em Sala se Aula e Voz do Professor. *Revista da Sociedade Brasileira de Fonoaudiologia, 17,* 398-404. https://doi.org/10.1590/S1516-80342012000400006 http://www.scielo.br/scielo.php?script=sci_nlinks&ref=000116&pid=S2179-6491201200030000800023&lng=en

Howard, D. M., & Angus, J. A. S. (2001). *Acoustics and Psychoacoustics* (2nd ed.). Oxford: Focal Press.

Huang, Y., & Benesty, J. (2004). *Audio Signal Processing for Next-Generation Multimedia Communication Systems*. New York: Kluwer Academic Publishers. https://doi.org/10.1007/b117685

Institute of Acoustics. http://www.ioa.org.uk

International Commission for Acoustics (ICA) (2007). *Brief Description of the International Commission for Acoustics.*

http://www.icacommission.org/introduction.html

ISO 3382-3:2012(en). https://www.iso.org/obp/ui/#iso:std:iso:3382:-3:ed-1:v1:en

Kahrs, M., & Brandenburg, K. (2002). *Applications of Digital Signal Processing to Audio and Acoustics*. New York: Kluwer Academic Publishers. https://doi.org/10.1007/b117882

Kelly, F. (2007). *Mathematical Modelling of the Internet*. Cambridge: Statistical Laboratory, Centre for Mathematical Science, University of Cambridge.

Knobel, K. A. B. (2007). *Influências do Silêncio e da Atenção na Percepção Auditiva: Implicação na Compreensão do Zumbido*. PhD Thesis, São Paulo: Universidade de São Paulo.

Kuttruff, H. (2000). *Room Acoustics* (4th ed.). Aachen: Institut für Technische Akustik, Technische Hochschule.

Lacerda, A. B. M., Magni, C., Morata, T. C., Marques, J. M., & Zannin, P. H. T. (2005). Ambiente Urbano e Percepção da Poluição Sonora. *Ambiente & Sociedade, 8,* 1-13. https://doi.org/10.1590/S1414-753X2005000200005

Lacerda, A. B. M., Morata, T. C., & Fiorini, A. C. (2001). Caracterização dos Níveis de Pressão Sonora em Academias de Ginástica e Queixas Apresentadas por Seus Professores. *Revista Brasileira de Otorrinolaringologia, 67,* 656-659. https://doi.org/10.1590/S0034-72992001000500009

Levandoski, G. (2013). *Qualidade de Vida e Conforto Acústico em Ambientes Educacionais*. PhD Thesis, Paraná: Universidade Federal do Paraná.

Magnus, M. C. M. (2014). *História da Modelagem Matemática na Educação Matemática Escolar Brasileira*.

Marion, G., & Lawson, D. (2008). *An Introduction to Mathematical Modelling* (pp. 1-32).

Martins, J. P. F., Magalhães, M. C., Sakae, T. M., & Magajewski, F. R. L. (2008). Avaliação da Perda Auditiva Induzida por Ruído em Músicos de Tubarão-SC. *Arquivos Catarinenses de Medicina, 37,* 69-74.

McLoughlin, I. (2009). *Applied Speech and Audio Processing*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511609640

Medeiros, L. B. (1999). *Ruído: Efeitos Extra-Auditivos no Corpo Humano*. Monograph: Centro de Especialização em Fonoaudiologia Clínica CEFAC.

Mendes, A. L. F., Lucena, B. T. L., Araújo, A. M. G. D., De Melo, L. P. F., Lopes, L. W., & Silva, M. F. B. L. (2016). Voz do Professor: Sintomas de Desconforto do Trato Vocal, Intensidade Vocal e Ruído em Sala de Aula. *CoDAS, 28,* 168-175. https://doi.org/10.1590/2317-1782/20162015027

Moscati, S. R. (2013). *Desempenho Acústico de Templos e Igrejas: Subsídios à Normalização*. Master Dissertation, São Paulo: Universidade de São Paulo.

Nascimento, L. B. P. (2009). *Influência de Variáveis Construtivas e de Uso de Equipamentos e Ocupação no Consumo de Energia em Edifícios de Escritório Localizados em Londrina-PR*. Master Dissertation, Londrina: Universidade Estadual de Londrina.

Nohama, P., & Silvério-Lopes, S. M. (2009). Influence of the Stimulating Frequency Involved in Analgesic Effects Induced by Electroacupuncture for Neck Pain Due to Muscular Tension. *Revista Brasileira de Fisioterapia, 13,* 152-158. https://doi.org/10.1590/S1413-35552009005000019

Oiticica, M. L., Alvino, I. L., & Da Silva, L. B. (2006). *Interferência dos Ventiladores na Qualidade Acústica das Salas de Aula da Rede Pública de Ensino Fundamental da Cidade de Maceió-AL*.

Pedersen, C. S. (2008). *Human Hearing at Low Frequencies: With Focus on Noise Complaints*. PhD Thesis, Denmark: Aalborg University.

Pereira Branco, E. R. P. (2013). *O ruído nas escolas*. Master Dissertation, Coimbra: Universidade de Coimbra.

Pereira, T. C. B., Da Silva, L. B., Coutinho, A. S., & Oiticica, M. L. (2004). Análise das Condições Acústicas em Sala de Aula Climatizada de Ambiente Universitário. In *Proceedings of the Enegep/Abebro Encontro Nacional de Engenharia de Produção* (p. 24).

Pippa, T. C. M. (2014). *A Função Logaritmo e a Régua de Cálculo*. Master Dissertation, São Paulo: USP.

Queiroz, L. R. S. (2006). Pesquisa Quantitativa e Pesquisa Qualitativa: Perspectivas para o Campo da Etnomusicologia. *Claves: Revista do Programa de Pós-Graduação em Música da Universidade Federal da Paraíba, 2,* 87-98.

Raichel, D. R. (2006). *The Science and Applications of Acoustics* (2nd ed.). Berlin: Springer.

Ramos, S. S. A. (2015). *Logaritmos: Uma Abordagem Didática*. Paraná: Universidade Federal do Paraná.

Rangu, M. (2007). *What Is Mathematical Modeling*?

Rodrigues, C. M. C. (2010). *Avaliação Acústica de um Estúdio de Gravação Implantado Numa Edificação Comercial*. Master Dissertation, Rio de Janeiro: Universidade Federal do Rio de Janeiro (UFRJ).

Santos, U. P., & Santos, M. P. (2000). *Exposição a ruído: Efeitos na saúde ecomo preveni-los*. São Paulo: Instituto Nacional de Saúde no Trabalho.

Siewe, Y. J. (2007). *Understanding the Effects of Aging on the Sensory System*. Oklahoma Cooperative Extension Service, 2140.1-2140.8.

Sociedade Brasileira de Acústic SBA. http://acustica.org.br

Société Française d'Acoustique. http://sfa.asso.fr/fr/accueil

Sodré, U. (2007). *Modelos Matemáticos*. Londrina: Matemática UEL.

Sonoda, A. V. (2016a). Análises dos Índices de Pressão Sonora no Campus I da UFPB em 2015 e Suas Implicações para a Educação. *RELACult—Revista Latino-Americana de Estudos em Cultura e Sociedade, 2,* 184-199.

Sonoda, A. V. (2016b). Influências de Parâmetros Acústicos na Educação do Século XXI: Contexto da Universidade Federal da Paraíba (UFPB) em 2015. *RELACult—Revista Latino-Americana de Estudos em Cultura e Sociedade, 2,* 301-308.

Takahashi, V. F. M., & Bertoli, S. R. (2012). Relação entre Atributos Acústicos e Características Arquitetônicas de Salas de Concerto Aplicando o Método da Síntese da Forma. *Ambient Construction, 12,* 193-205.
https://doi.org/10.1590/S1678-86212012000100013

Talbot-Smith, M. (1999). *Audio Engineer's Reference Book* (2nd ed.). Waltham, MA: Focal Press.

Tavares, M. S. A. (2016). *Um Panorama dos Níveis de Ruído para Conforto Acústico de Ambientes de Ensino com VDT em Áreas das Regiões Brasileiras*. Undergraduate Course, João Pessoa: Universidade Federal da Paraíba (UFPB).

Taxini, C. L., & Guida, H. L. (2008). Análise dos Níveis de Pressão Sonora dos Sons Emitidos por Brinquedos Ruidosos. *Revista de Iniciação Científica da FFC, 8,* 31-38.

Taylor, B. N., & Thompson, A. (2008). *The International System of Units* (SI). National Institute of Standards and Technology Gaithersburg.

Toole, F. E. (2008). *Sound Reproduction: Loudspeakers and Rooms*. Waltham, MA: Focal Press. https://doi.org/10.6028/NIST.SP.330e2008

Venslauskas, M., Ostasevicius, V., & Vilkinis, P. (2017). Influence of Low-Frequency Vibrations on Blood Flow Improvement in Human's Limbs. *Bio-Medical Materials and Engineering, 28,* 117-130.

Watkinson, J. (1998). *The Art of Sound Reproduction*. Waltham, MA: Focal Press.