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# An Overview of Acoustical Features in Brazilian School Buildings

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**Abstract [666]** Noise pollution in urban areas has been an increasing problem in modern cities. High levels of different noise sources impact on the school environment. On the other hand, buildings are not designed to protect intrusive noise in developing countries. Specifically in Brazil, architects and engineers do not take into account the acoustic comfort of educational buildings. The importance of having an adequate acoustic environment is well known or students achievement and learning abilities can be lowered. As far as the teachers are concerned, noisy classrooms induce them to raise their voices, even though this attitude does not guarantee better listening conditions.

This study presents the results of an evaluation of schools in southern Brazil, which aims to give design and building directives for the construction of new schools with adequate acoustic quality. The evaluation comprehends three parts: a) a survey of the architecture features of existing school buildings; b) questionnaires answered by the school users and; c) measurements of acoustical parameters such as background noise level, reverberation and early decay time. The results show that the situation is far from the ideal, since there are many acoustical problems originating from bad building design. The questionnaires show that users reckon their poor acoustic conditions and measured noise levels and reverberation and early decay times are outside recommended limits. The highest intelligibility level found was 88% and the majority of schools presented lower levels.

## 1 INTRODUCTION

Educational buildings should have adequate conditions to allow students and teachers to carry on their teaching and learning activities. It is a major issue to have an adequate acoustical environment when it comes to schools. The influence of high noise levels and low intelligibility scores may lead to several problems, such as decreased learning abilities [1], vocal disorders and communication misunderstandings [2].
This paper presents the acoustical evaluation of educational buildings in southern Brazil. The main target is to give a basis for future legislation on acoustics of educational buildings. Therefore, the study was planned to diagnose the present situation and to propose design recommendations for architects and engineers.
The study comprehends three parts: a) a physical survey of the architectural building characteristics, b) a subjective evaluation performed by means of applied questionnaires, and c) various acoustical

measurements. The intended goal of the first item is to make a preliminary analysis of the present situation. Layout evaluation, interviews and architectural survey were carried out. The questionnaires were applied in order to get the users perspective, thereby obtaining a post-occupational evaluation. Lastly, the third phase included the acoustical measurements of background noise levels and reverberation and early decay times. An estimate of intelligibility levels was performed from the measured data.

## 2 ARCHITECTURAL SURVEY

An architectural analysis was conducted in order to obtain a preliminary overview of the acoustical conditions of the school buildings. Following the interviews, it becomes clear that there is a significant distance between the architects' designers and the site of the building. All the design is made in the central office in the city of Florianópolis and only a few visits to the site are made. This may be a negative aspect because, often, they do not even know the site of the school and its noise sources, before the construction.

The standardisation in the topic "acoustic of educational buildings" is far away from the ideal as there are no major recommendations in the country. Also, many architects do not have the necessary knowledge on architectural acoustics. The result is an urgent need for creating minimum standards for those buildings.

Typologically, the architectural survey concluded that internal acoustical zoning of the area and the building are not considered. There is a standard building plan that many times is just reproduced in places with different requisites. This standard is presented in Figure 1. The same figure shows the noise sources. It can be seen that many sources, like parking lot, internal halls and sports court, are very close to the classroom; an environment that requires minimum ambient noise.

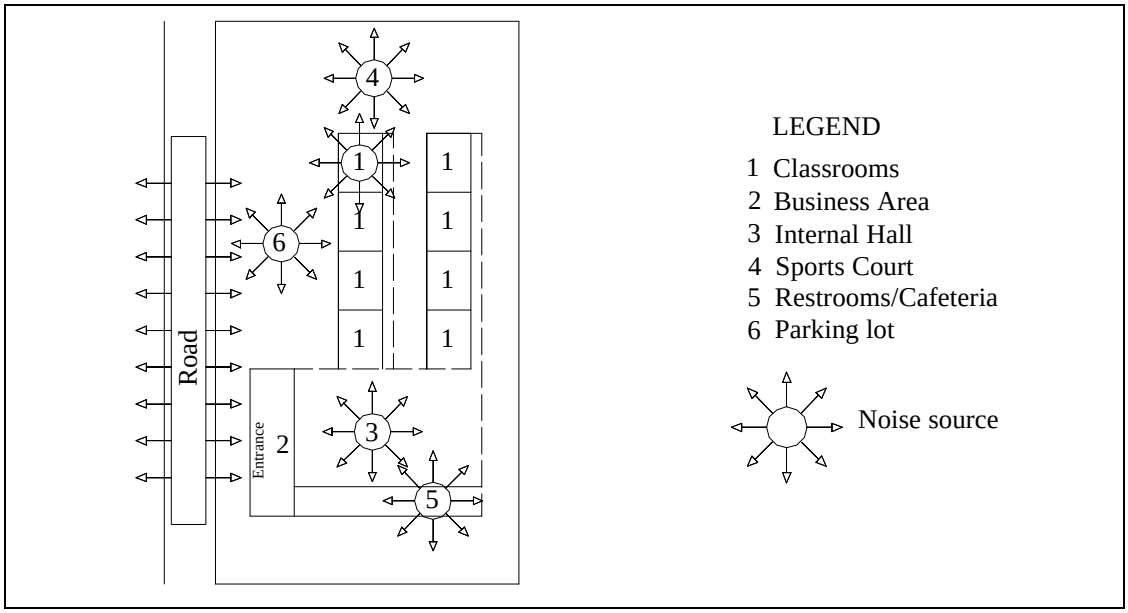


Figure 1: *Noise sources in a standard school*

The materials are not properly chosen to avoid noise break-in and control reverberation. It is common to use single glazing panels beside a very noisy street. Almost exclusively hard materials are used on the coverings of floors, walls and ceilings. These materials are ceramic tiles, concrete, plaster and plastic. Considering that many classrooms have high ceilings, this leads to high reverberation times. Sealing of openings does not exist. In the same manner as above, Figure 2 now presents a standard classroom with the noise sources that impact on it.

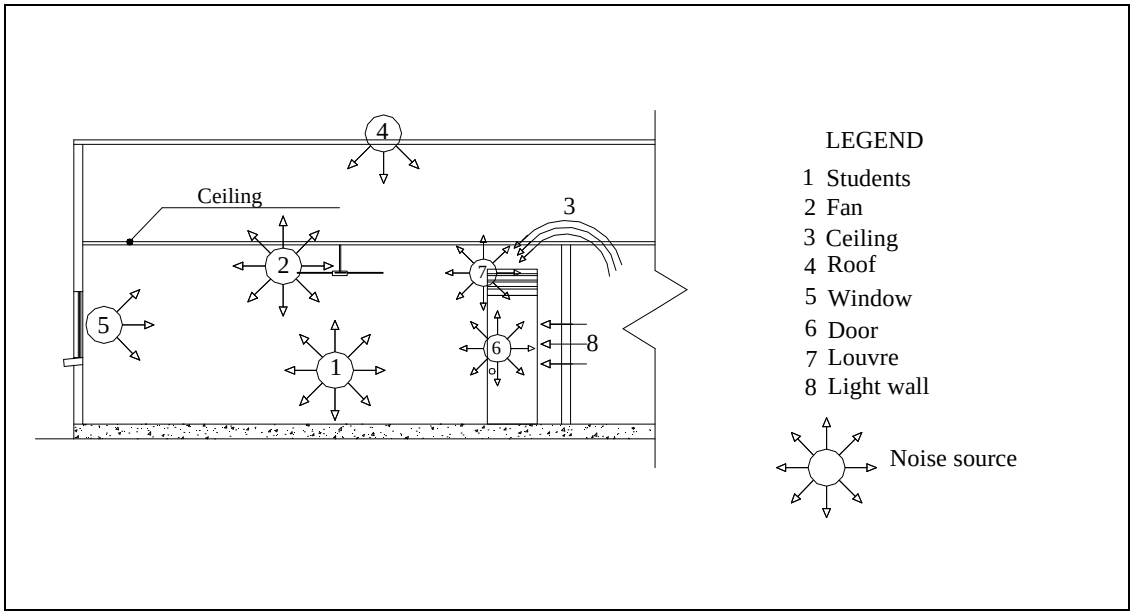


Figure 2: *Sound sources in a standard classroom*

The maintenance of the school buildings is pretty bad and only helps to make the situation worse. Many doors do not even close because there are no locks and several windows have broken panes, all due to bad maintenance.

The architectural survey concludes that the schools may have serious acoustical problems such as high background noise levels, poor aerial sound insulation of partitions and elevated reverberation times.

## 3 QUESTIONNAIRES

Figure 3 demonstrates that 79% of students hear noise from adjacent classroom. Teacher responses are very similar with 76% of them hearing noise from adjacent classrooms. It can be considered a significant amount and might be the result of a low sound insulation performance of partition walls.

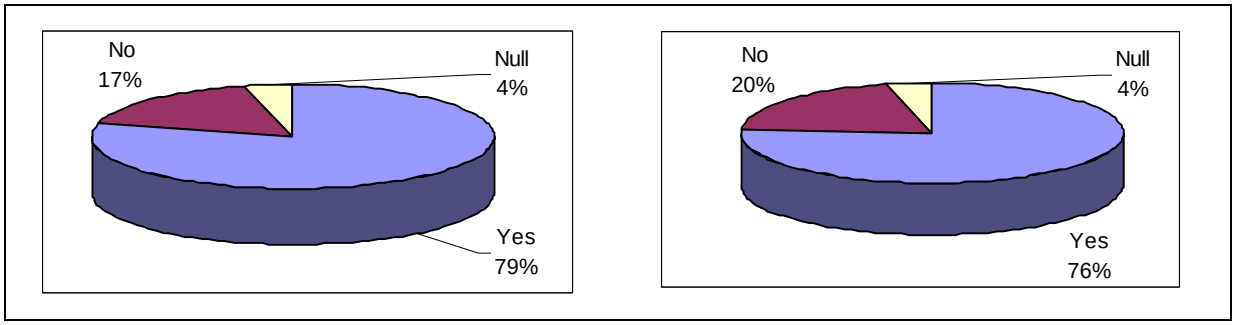


Figure 3: *Students and teachers responses: "Can you hear noise from adjacent classrooms?"*

Figure 4 presents how respectively 42% and 43% of students and teachers consider their classroom a noisy place. Again, it is an elevated amount of respondents that complain about noise. The related noise can originate either from inside or outside the classroom. The results for the related sound sources indicate the adjacent classes, recreational areas and corridors as the main sources. The students reported that spots close to doors and windows and at the back part of classrooms are the noisiest places. It does not come as a surprise that close to openings are the areas with higher sound transmission and, consequently, where one would expect more complaints. In Brazil, a country of hot weather conditions, it is usual to have opened doors and windows during classes all year around.

As for the back part of the room, this is the place where teachers have more difficulty controlling chatting among students.

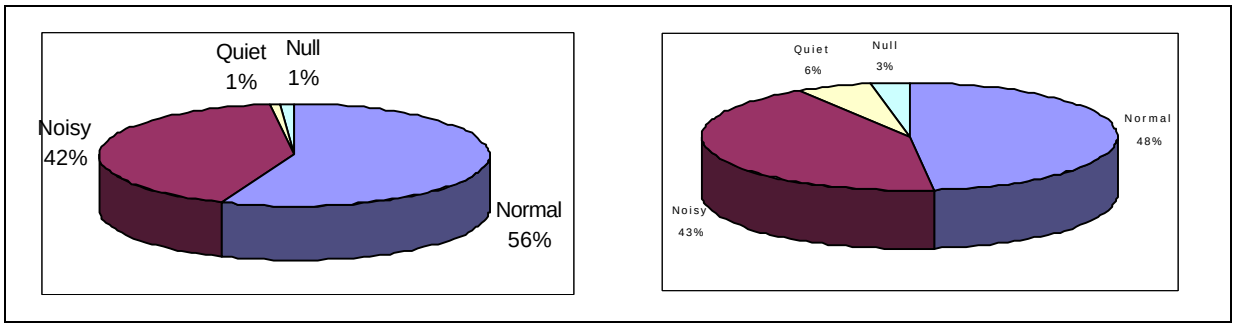


Figure 4: *Students and teachers responses: "How do you consider your classroom?"*

Figures 5 shows the relative evaluation of intelligibility. 38% of students reported difficulty in hearing the teacher and some of them pointed out that the teacher's voice "sounds strange". On the other hand, 40% of teachers have a similar problem when students ask them questions. Yet, it is well known that good intelligibility conditions can be achieved by the correct design of classrooms, that is to say, an appropriate sound insulated envelope and an adequate amount of sound absorption surfaces.

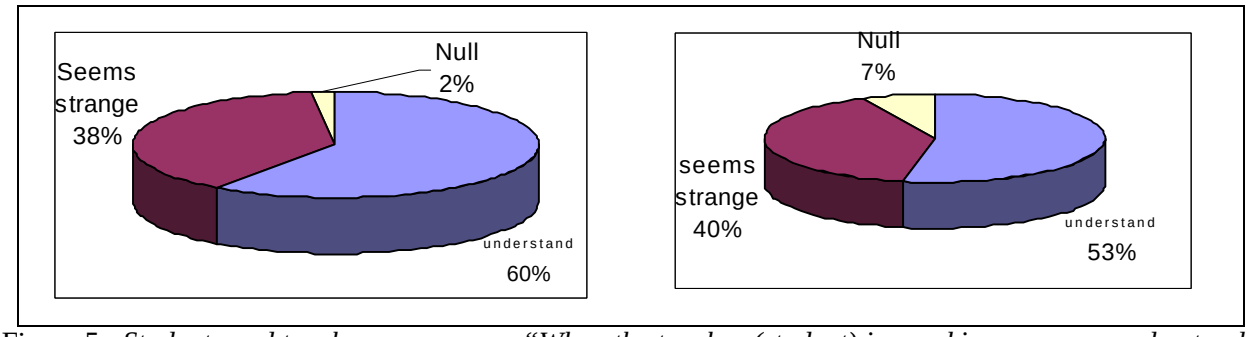


Figure 5: *Students and teachers responses: "When the teacher (student) is speaking, can you understand clearly what it is being said or does it sound strange*?

Extracted from the students' responses, Figure 6 shows that 68% consider that noise influences academic achievement. As far as the teachers are concerned, 91% of them considered the same. It is a good issue to have users that know the importance of acoustical conditions on the academic achievement.

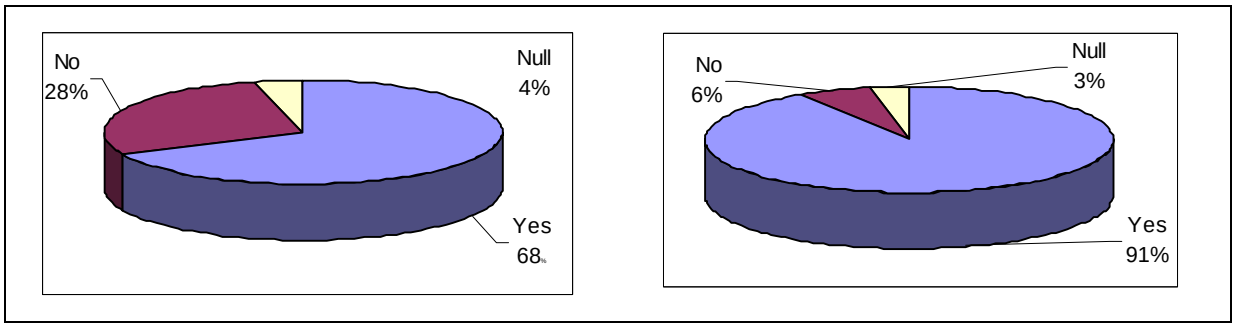


Figure 6: *Students and teachers responses: "Does noise influence academic achievement?"*

The next figures are related to vocal aspects of teachers. The first one shows that 59% of them have some kind of vocal disorder and 72% raise their voice to teach. It may be the explanation for the vocal disorders.

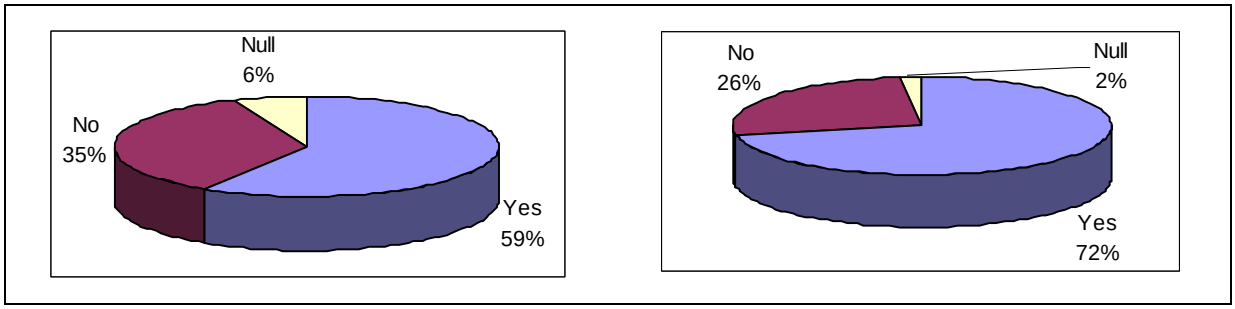


Figure 7: *Teachers responses: "Do you have or have you had vocal disorders related to the use of voice as a teacher?" and "Do you consider it necessary to raise your voice to teach?"*

Figure 8 reveals that 55% consider the excess of noise as the main cause of vocal disorders, followed by their own way of speaking (23%)and the classroom architecture (19%).

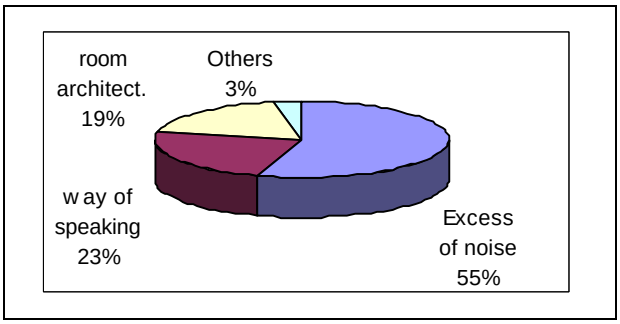


Figure 8: *Teachers responses: "In your opinion, which are the causes for your vocal disorders?"*

## 4 ACOUSTICAL MEASUREMENTS

The acoustical measurements were performed in 5 different classrooms in 5 schools. Table 1 shows recommended background noise levels in classrooms in many countries, as stated by Vallet [3]. Also, Bradley [4] reported that 30 dB would be the acceptable level inside classrooms and +15dB(A) is the ideal signal-to-noise ratio to achieve desirable intelligibility [5].

Table 1: *Recommended background noise levels (BNL) for classrooms [3]*

| Country | Year of the standard | Noise descriptor | Recommended BNL |
|---|---|---|---|
| Belgium | 1977/ 87 | Leq (A) | 30-45 |
| Brazil | 1987 | dB(A) | 40-50 |
| France | 1995 | Leq (A) | 38 |
| Germany | 1989 | – | 30 |
| Italy | 1975 | – | 36 |
| Portugal | – | – | 35 |
| Sweden | 1995 | Leq | 30 |
| Turkey | 1986 | Leq | 45 |
| UK | 1997 | Leq 1h | 40 |

Figure 9 presents the results of background noise levels ($Leq_{(a)3min}$ ) and peak sound pressure levels. It is important to know not only the medium noise levels, but also the peak levels. This transitory level may be harmful as it distracts people and makes students lose the focus in the class. All of the five classrooms analysed had $Leq_{(a)3min}$ above the level recommended by several international rules. The values range from 51,5 to 70,5 dB(A). To achieve minimum S/N ratio of +15 dB(A), teachers

would have to raise their voice to 85 dB(A) in some schools, which would be not possible without getting vocal disorders.
Peaks ranged from 68,5 dB(A) to 88,3 dB(A). These values are not acceptable inside a room where it is supposed to have learning activities.

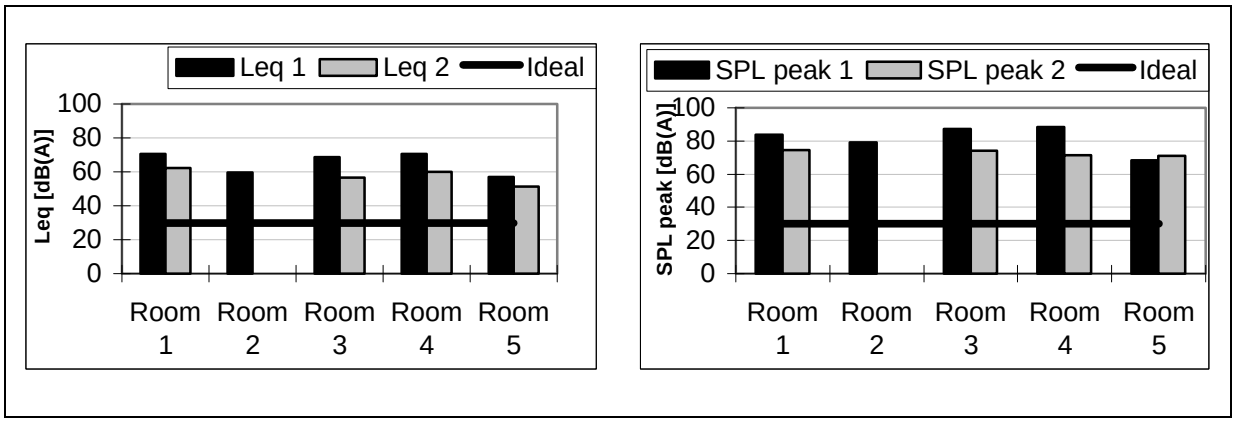


Figure 9: *Results of Leq and SPLpeak*

Table 2 below presents the recommended reverberation times for classrooms as Vallet [3] and Fernandes [6].

Table 2: *Recommended reverberation times (RT) for classrooms [3,6]*

| Country | Standard | Recommended RT | Comment |
|---|---|---|---|
| Brazil | – | – | – |
| Finland | – | 0,6 – 0,9 | – |
| France | – | 0,4 – 0,8 | 250 $m^3$ rooms, 500 – 2kHz |
| Italy | – | 0,5 – 2 | Depends on frequency and vol. |
| Portugal | Lei 251/87 | 0,6 – 0,8 | 500 – 4kHz |
| UK | BB 87 | 0,5 – 0,8 | – |
| USA | ANSI | 0,6 – 0,7 | S/N ≥ 15 dB(A) |
| USA | ASHA | 0,4 | S/N ≥ 15 dB(A) |
| WHO | – | 0,6 | – |

RT and EDT in all of the classrooms evaluated are above the 0,5 seconds recommended by the literature. Values range from 1,15 to 1,68 seconds for RT and 0,83 to 1,30 seconds for EDT, as it is shown on Figure 10. Again, this situation interferes with the correct use of the classroom.
Finally, an estimate was made of intelligibility levels through the correlation of $Leq_{(a)3min}$, S/N ratio and RT, as suggest by Bradley [7], in the ideal condition. Considering that the human voice at 1 meter distance [8] has a sound pressure level of about 63 dB(A), and the value of $L_{eq}$ 56,8 dB(A), the signal-to-noise ratio results in 6,2 dB(A). Correlating S/N ratio with 1,15 seconds of reverberation time, the final intelligibility level is 88%. This is very poor, since all of the other classrooms are below this level and values close to 100% are desirable.

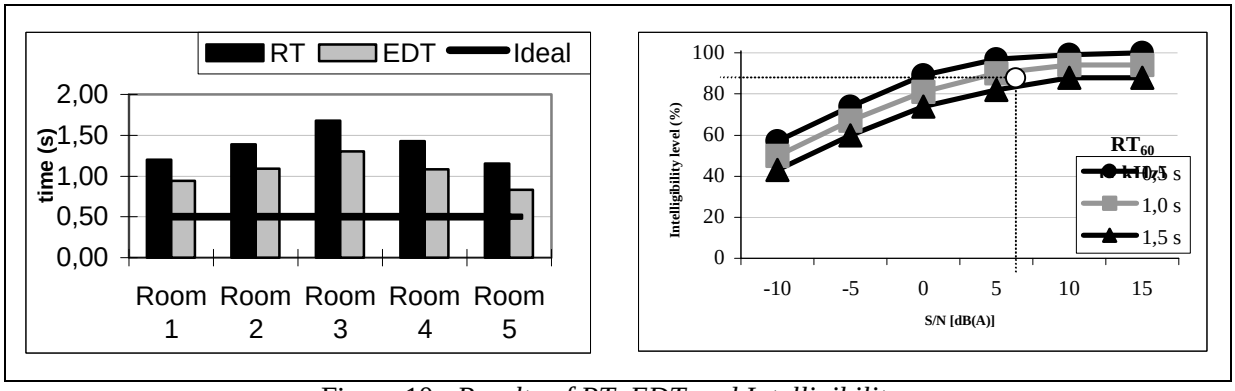


Figure 10: *Results of RT, EDT and Intelligibility*

## 5 SUMMARY

This paper presented an overview of the evaluation of educational buildings in southern Brazil. The issue was evaluated in tree parts: architectural survey, questionnaires and acoustical measurements. First, the architectural features of those buildings regarding acoustical condition were analysed. The results pointed out that the buildings may have several acoustical deficiencies leading to high background noise levels and elevated reverberation times.

The questionnaires completed by the users – students and teachers – presented similar results wherein both complain about noise in their classroom and about not understanding each other during lectures and questions. Also, the teachers said that they have vocal disorders originating from their jobs. These results agree with the conclusions from the earlier architectural analysis. The acoustical condition might have problems.

Finally, the results of the acoustical measurements of background noise levels, reverberation times and early decay times confirm that the noise levels inside the classroom are far above the acceptable and, the internal acoustical quality is precarious with high values of reverberation times. Concluding the study, the intelligibility level for the best school analysed proved that architectural survey, questionnaires and acoustical measurements led to the same result: that the acoustics is inappropriate in those school buildings.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] I. Caric; M. Cudina. “Disturbing Effects of Noise in Classroom of a Primary School”, in: *Proceedings of 17th International Congress on Acoustics*, Rome, 2001.

[2] R. Penteado; I. Pereira. “A Voz do Professor: Relações entre Trabalho, Saúde e Qualidade de Vida”, *Revista Brasileira de Saúde Ocupacional*, **95/96**, v.25, pp.109-130.

[3] M. Vallet, “Some European Standards on Noise in Educational Buildings”, in: *Proceedings of International Symposium on Noise Control for Educational Buildings*, Istanbul, 2000, pp.13-20.

[4] J. S. Bradley, “Speech intelligibility studies in classrooms*” J. Acoust. Soc. Am.*, **80 (3),** 846-854 (1986).

[5] S. Airey, “The Effects of Classroom Acoustics on School Teachers”, in *Proceedings of International Symposium on Noise Control for Educational Buildings*, Istanbul, 2000, pp.21-30.

[6] A. Fernandes, “Impacto do Ruído de Tráfego em Edificações Escolares: Um Estudo de Caso”, Master Dissertation, PPGEC, Federal University of Santa Catarina, Brasil, 2002.

[7] J. S. Bradley, “Speech intelligibility in classrooms”, *J. Acoust. Soc. Am.*, **80 (3)**, 846-854, (1986).

[8] M. Egan, Architectural Acoustics, McGraw Hill, New York 1988.