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CHARACTERISATION AND ACOUSTIC CORRECTION OF CLASSROOMS, CASE STUDY: FACULTY OF ARCHITECTURE IN CONSTANTINE, ALGERIA

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ABSTRACT

Teaching spaces such as classrooms are spaces intended to communicate pedagogical content orally to learners, and for this function their design must ensure listening comfort through appropriate choice of finishing materials and correct acoustic design. In room acoustics, the acoustic characterization of spaces is done by calculating certain acoustic criteria, in order to conclude whether the acoustics are good or bad. The simulation evaluation of a space makes it possible to calculate objective criteria such as reverberation time, speech intelligibility and clarity in addition to background noise and to carry out an acoustic correction. The objective of this work is to evaluate, using the tool of simulation, the variation of the acoustic conditions of two classrooms similar in their architecture but which differ by the height of the ceiling and therefore have different volumes. In order to obtain optimal values for the two classrooms of the calculated acoustic criteria, the absorbent materials will be placed according to the architectural peculiarities of the two workshops.

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Introduction.

Classrooms and workshops are spaces designed to communicate educational content orally to learners, and as such these spaces must ensure listening comfort through appropriate layouts and correct acoustic design. Classroom acoustics are therefore essential to create an environment conducive to learning (Mealings.K.T.A., 2022). Recent research published in 2022 summarizes the state of the art of 56 papers from the last 19 years on the effect of classroom acoustics on student's learning achievement, identifying the acoustic parameters and their values with the greatest influence on student performance at different ages. In this research, the authors conclude that "the literature has consistently highlighted the positive effects of good acoustics on speech intelligibility" ....

Conversely, poor classroom acoustics can adversely affect speech intelligibility, cognitive skills, comprehension and academic performance, leading to perceptions of mental and physical discomfort» (M.Hodgson, 1999). The main criteria contributing to poor acoustics are high levels of background noise and longer reverberation times (producing an echo effect), which leads to a deterioration in vocal communication between learners and teachers (Mealings.K.T.A., 2022). Background noise is sound that makes it difficult to hear, and can originate from a number of places; such as noise coming from outside the building, or noise coming from inside the building, such as students talking in the corridor.

The main aim of this project is to use simulation tools to assess the variation in acoustic conditions in two classroom which are similar in terms of architecture, but differ in terms of ceiling height, and therefore have different volumes. Another objective is to use different placements of absorbent materials according to the particularities of the two workshops, in order to obtain optimal values for the main acoustic parameters of speech in both workshops.

I.1. Literature review.

By simulating or measuring a room's acoustics, we can calculate objective criteria such as reverberation time, speech intelligibility and clarity in addition to background noise, in order to conclude whether acoustics are good or bad. The relationship between background noise, reverberation time and speech intelligibility in classrooms has been studied by (Bradley and Hodgson) who concluded that good acoustic design should be based on speech intelligibility reverberation time and that background noise is a highly critical factor in speech intelligibility (M.Hodgson, 2002).

Concerns about acoustic conditions in classrooms and the importance of the criteria studied by (Bradley and Hodgson) have led many researchers to propose standards or guidelines following the objective and subjective evaluation of these acoustic criteria in classrooms.

In a study (Giuseppina.E.P, 2018) addressing the acoustic parameters that influence the performance of adult learners, they suggest the following standards for acoustic criteria; reverberation times should be 0.7 s, and intelligibility should be > 0.60. However, 100% speech intelligibility is possible with a reverberation time range of up to 0.4 to 0.5 s (Fratoni, 2021). According to ISO 3382, for small spaces such as classrooms, the optimum values for clarity C50 At frequency 500Hz and 1000 Hz are between -1dB and +3dB. (ISO3382-2, 2008) Acoustics - Measurement of room acoustic parameters.

Poor room acoustics can be improved by the use of absorbing acoustic elements to control sound fields. (Scoczynski Ribeiro, 2021) In the case of the architecture teaching classroom, where practical work is carried out, teaching takes place not only in the form of lectures, but also in the form of self-study through work carried out by students alone or in groups and then corrected by the teacher. This particularity in teaching practice will have an impact on ambient noise, so background noise will be measured during teaching activities inside the two classrooms; the measured value of the background noise will be introduced for the simulation of acoustic criteria. In addition, the space requires adequate selection and placement of acoustic elements to achieve optimum acoustic quality.

II. Materials and methods.

The Faculty of Architecture and Urban Planning of Constantine has two types of classroom that are different in terms of their volumes. Classrooms of 445 m³ and those of 356 m³, the latter being of two types: those with a ceiling height of 4m and those with a height of 5m. These rooms differ in volume, which is an important criterion in acoustic evaluation. The classroom chosen for this study have a volume difference of 84 m3.

The Faculty of Architecture and Urban Planning of Constantine has two types of classroom that are different in terms of their volumes. Classrooms of 445 m³ and those of 356 m³, the latter being of two types: those with a ceiling height of 4m and those with a height of 5m. These rooms differ in volume, which is an important criterion in acoustic evaluation. The classroom chosen for this study have a volume difference of 84 m3. (Fig 1).

Figure 1. Interior views of two classrooms.

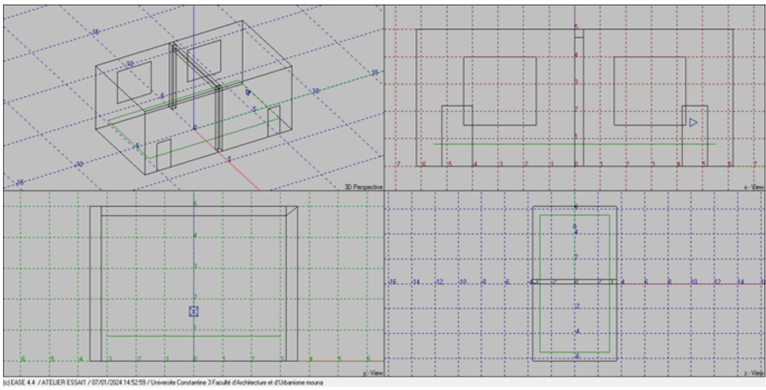


Figure 2. Modeling classrooms with EASE. *Figure 3. Background measurements.*

Both types of classrooms have a rectangular floor plan, with two wooden doors and two large aluminum windows on opposite longitudinal walls. They are furnished with drawing chairs and tables, and a desk for the teacher. All walls and ceiling have a coat of painted plaster. Plywood panels are hung on the walls to display students' work. The windows are fitted with light fabric curtains. The floor is tiled.

Table 1. Characteristics of the classroom's studied.

Classrooms	Volumes m^3	Area m^2	Absorption coefficients of different materials in the classrooms			
The large classroom A	445 m^3	89 m^2	Plaster	Tile	Wood	Glass
			0.O3	O.01	0.015	0.03
The small classroom B	356 m^3	89 m^2				

Numerical simulation and modeling software can be used to study acoustic phenomena, from the simplest to the most complex. The numerical approach, while complementary to the experimental approach, is essential for qualifying sound phenomena in a space and calculating the various acoustic criteria. (Kouzeleas.S, 2024)

In our study, we'll be using the EASE4.4 software, distributed by AFMG. EASE 4.4 is an acoustic simulation software package. It can be used to model rooms, acoustic and electro-acoustic sources, and to calculate numerous parameters used in room acoustics. The acoustic criteria calculated with EASE are TR60, C50 clarity and intelligibility. Based on the plans, sections and facades of the two workshops, the model was created using EASE. The three-dimensional visualization of the space takes the form of a digital model made up of facets to which are associated acoustic parameters such as the absorption coefficient of the materials. (Fig 2) The absorption coefficient αsab is the ratio between the acoustic energy absorbed by a material and the incident energy; it varies between 0 and 1 as a function of frequency. In order to achieve the objective defined in the introduction, each workshop will be modeled, based on the definition of the 3D geometry of the two classrooms and the absorption properties of the materials (of the various walls, floors, ceilings, openings) over the octaves centered on 125 to 8 KHZ. The simulated acoustic criteria values will then be compared with recommended values, and optimized by appropriate placement of absorbing materials. Finally, a comparative analysis of the acoustic criterion values before and after acoustic correction will be carried out. (Yang W, 2010)

Simulation of acoustic criteria.

The simulation of acoustic criteria was launched taking into account the real conditions under which teaching takes place in the selected classrooms. The specific objectives of these measurements were to obtain a representative average of the background noise inside classrooms while the students were working. To this end, the sound level meter was placed at various points in the classroom for an average period of 5 to 15 minutes. As shown in the photo, background noise levels varied between 50 and 70dB. (Fig 3) (Elmehdi HM, 2018)

At the end of these measurements, the average background noise level was close to 65dB, a value used for all calculations, in addition to the material absorption coefficients over the octaves centered on 125HZ at 8 KHZ. of the various faces and openings of the classrooms. (Table 1)

In addition, the sound source was placed where the teacher usually stands, representing a human voice without a microphone, with an intensity of 60dB. Finally, the hearing area extends over the entire classroom surface for seated students. (Zannin PHT, 2007)

III. Results.

The values of the simulated acoustic criteria Tr 60, clarity C50 and intelligibility STI of the two classrooms are given by EASE in graphical form, also visualized on the audience area in mapping.

Reverberation time T60

The simulated reverberation time values for the two workshops provided by EASE in the 125 to 2000 Hz octave bands are shown in the curves in the figure, as well as in the graph. The Tr results are higher than the optimum values, estimated at 0.7 s, indicating poor acoustics due to the high reverberation time values. (Fig 4).

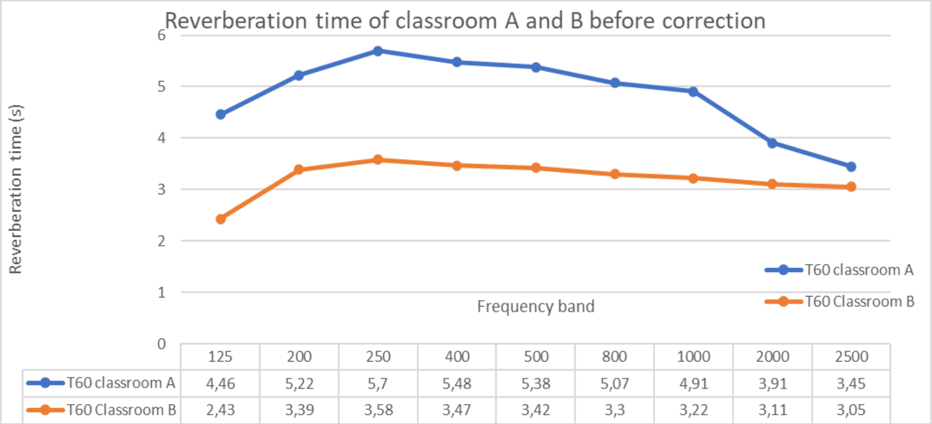


Figure 4. Reverberation time T60 of classroom A and B before correction C50 clarity.

The C50 values at 1000Hz frequency, simulated for classroom A and B, are shown in Table 2. The value shows poor clarity for both classrooms, with average values of -7dB, the optimum values being between -1dB and +3dB (ISO 3382-2, 2008)).

Table 2. Average, minimum and maximum clarity values for classrooms A and B.

C50 values of A and B classroom	Classroom A	Classroom B
Average values of C50	-7.01 dB	-7.07dB
Minimum C50values	-7.90 dB	-7.67 dB
Maximum C50values	-1.96 dB	-2.57 dB

STI intelligibility.

The simulated STI results for both classrooms show poor speech intelligibility, due to the influence of the high reverberation time and background noise, which is higher than the standard for classrooms, estimated at 35dB. These results are illustrated in Table 3, for classrooms A and B the maximum STI values are equal to 0.31 and 0.43 respectively. Optimum intelligibility, as mentioned in the introduction, should be equal to or greater than 0.6.

Table 3. Average, minimum and maximum STI values for classrooms A and B.

STI values before correction	Classroom A	Classroom B
Average values of STI	0.2	0.35
Minimum STI values	0.19	0.33
Maximum C50values	0.31	0.43

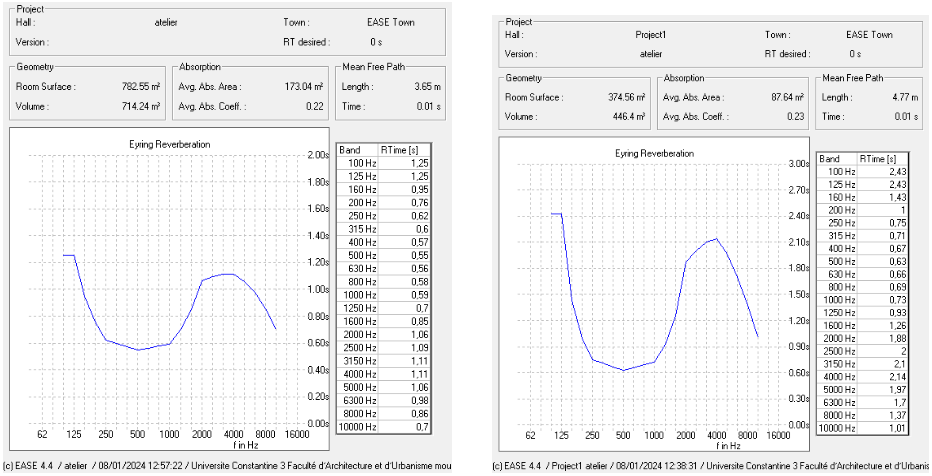
Acoustic correction of classrooms A and B.

Following analysis of the results of the three acoustic criteria, "Reverberation time T60, C50 and STI", with the aim of achieving acoustic comfort, we studied different solutions for adding absorbent panels to meet the requirements of two classroom. Classrooms A and B have reverberation times of 5.38s and 3.42s respectively, while the recommended Tr for a classroom is 0.7s. We therefore needed to reduce the reverberant surfaces by installing absorbent panels to reduce the T60 of classroom A by 4s and that of classroom B by 2s.

To achieve this, we reduced the height of workshop A by installing acoustic panels in a false ceiling, in addition to two strips of absorbent panels on the wall opposite the large windows and the back wall. Subsequently, acoustic panels were installed in the ceiling of classroom B. We chose durable acoustic panels made from two sheets of perforated MDF containing cellulose wadding. The construction of these panels is explained in the reference document. (Champilou, 2021)

T60 results after correction.

The reverberation time of classroom A at 500Hz before treatment was 5.38 and after acoustic treatment with absorbent panels was 0.63. classroom B before treatment had a Tr of 3.42 and after acoustic treatment with absorbent panels the 500Hz T60 was equal to 0.55s, so the acoustic treatment of both workshops helped improve communication conditions in the classrooms. (Fig 5)



Hall : atelier
Town : EASE Town
Version :
RT desired : 0 s
Room Surface : 782.55 m²
Volume : 714.24 m³
Avg. Abs. Area : 173.04 m²
Avg. Abs. Coeff. : 0.22
Length : 3.65 m
Time : 0.01 s

Band	RTime [s]
100 Hz	1,25
125 Hz	1,25
160 Hz	0,95
200 Hz	0,76
250 Hz	0,62
315 Hz	0,6
400 Hz	0,57
500 Hz	0,55
630 Hz	0,56
800 Hz	0,58
1000 Hz	0,59
1250 Hz	0,7
1600 Hz	0,85
2000 Hz	1,06
2500 Hz	1,09
3150 Hz	1,11
4000 Hz	1,11
5000 Hz	1,06
6300 Hz	0,98
8000 Hz	0,86
10000 Hz	0,7

(c) EASE 4.4 / atelier / 08/01/2024 12:57:22 / Universite Constantine 3 Faculté d'Architecture et d'Urbanisme mou

Hall : Project1
Town : EASE Town
Version : atelier
RT desired : 0 s
Room Surface : 374.56 m²
Volume : 446.4 m³
Avg. Abs. Area : 87.64 m²
Avg. Abs. Coeff. : 0.23
Length : 4.77 m
Time : 0.01 s

Band	RTime [s]
100 Hz	2,43
125 Hz	2,43
160 Hz	1,43
200 Hz	1
250 Hz	0,75
315 Hz	0,71
400 Hz	0,67
500 Hz	0,63
630 Hz	0,66
800 Hz	0,69
1000 Hz	0,73
1250 Hz	0,93
1600 Hz	1,26
2000 Hz	1,88
2500 Hz	2
3150 Hz	2,1
4000 Hz	2,14
5000 Hz	1,97
6300 Hz	1,7
8000 Hz	1,37
10000 Hz	1,01

(c) EASE 4.4 / Project1 atelier / 08/01/2024 12:38:31 / Universite Constantine 3 Faculté d'Architecture et d'Urbanis

Figure 5. T60 results of classrooms A and B after correction.

Table 4. T60 (250 to 2000 Hz) results of classrooms A and B after correction.

Reverberation time T60(s)	Frequency band Hz					
	250	400	500	800	1000	2000
classrooms A	0.75	0.67	0.63	0.69	0.73	1.88
classrooms B	0.62	0.57	0.55	0.58	0.59	1.06

C50 clarity results after correction.

The decibel values of C50 clarity for both classrooms moved to positive mean values, with the C50 for classroom A and B for the 1000 Hz frequency rising from 7.01 dB to 1.61 and from 7 to 1.27

respectively. These post-correction C50 values indicate a very significant improvement in communication clarity. (Fig 6, Fig 7)

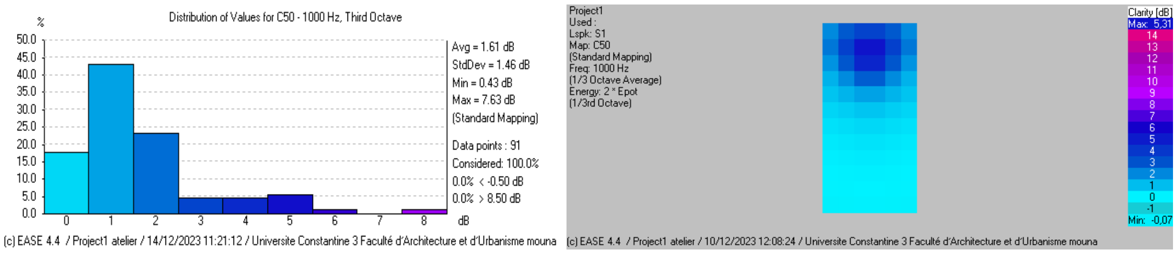


Figure 6. C50 clarity results after correction of classroom A.

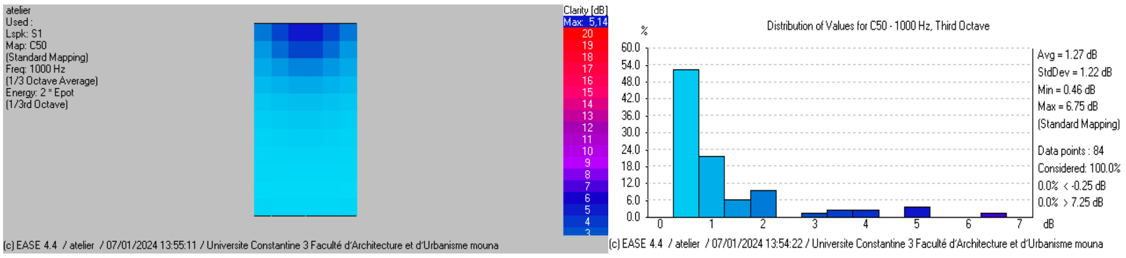


Figure 7. C50 clarity results after correction of classroom B.

Table 5. C50 classroom A and B before and after correction.

C50 values of A and B classroom	Classroom A before correction	Classroom A after correction	Classroom B before correction	Classroom B after correction
Average values of C50	-7.01 dB	1.61dB	-7.07 dB	1.27dB
Minimum C50values	-7.90 dB	0.43 dB	-7.67 dB	0.46 dB
Maximum C50values	-1.96 dB	7.63 dB	-2.57 dB	6.75 dB

STI results after correction.

The average STI intelligibility values for the two workshops are respectively equal before the correction to 0.2 and 0.3 and after the correction they are equal to 0.58 and 0.57. These values are very close to the optimal value equal to 0.6. It should be noted that the STI can be further improved by reducing background noise through adequate acoustic insulation of the workshops. (Fig8, Fig9).

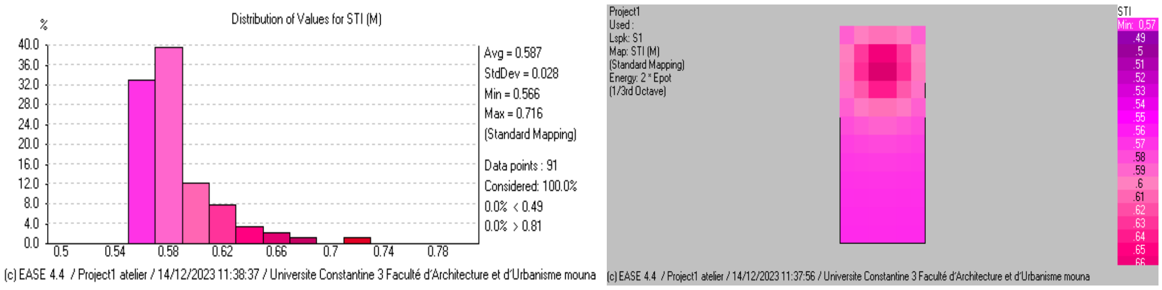


Figure 8. STI results after correction of classroom.

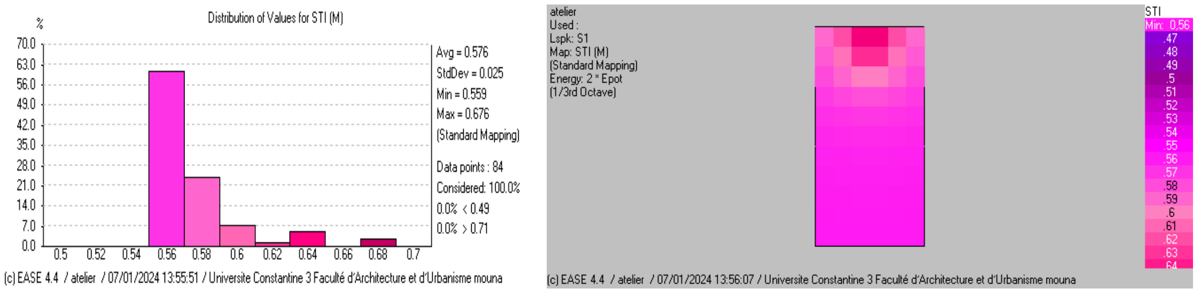


Figure 9. STI results after correction of classroom B.

Table 6. STI classrooms A and B before and after correction.

STI values before and after correction	Classroom A before correction	Classroom A after correction	Classroom B before correction	Classroom B after correction
Average values of STI	0.206	0.587	0.351	0.576
Minimum STI values	0.192	0.566	0.337	0.559
Maximum C50values	0.311	0.716	0.437	0.676

IV. Discussion.

Our study is an attempt to add to the body of scientific literature in the field of investigation of numerical simulation in the specific case of classroom acoustics. Our results complement this field of research by emphasising the importance of covering materials and certain design choices as determining criteria for the acoustic quality of classrooms. In the light of the results obtained, we feel that several considerations should be taken into account when assessing the quality of oral communication in classrooms.

- Numerical simulation is a means of investigation that makes it possible to predict acoustic quality by integrating the performance of materials and modelling spaces, acoustic sources and background noise measurements. In our study of classrooms, we identified two types of teaching activity: conventional teaching and group work. Background noise was measured in both cases. In order to take account of the most unfavourable acoustic conditions, the acoustic criteria were calculated using the highest background noise measurement, equal to 60 dB.

- According to the scientific literature, it is crucial to choose the acoustic criteria to be calculated in relation to the nature of the activities linked to oral communication in teaching spaces. To this end, three acoustic criteria need to be calculated: reverberation time Tr60, speech-specific clarity C50 and speech intelligibility STI. These three parameters are essential for evaluating the acoustic conditions and making the necessary corrections to help ensure comfortable listening and learning.

- The results of the acoustic criteria simulated for the two classrooms show a reverberation that exceeds the standards established for teaching spaces. Comparing the Tr values of the two classrooms, we note the impact of the great height of classroom A on the Tr results, which are five times higher than the optimum values. In fact, despite the similarity of the two classrooms, the difference of 1 metre in height between workshop A and B resulted in an increase equal to 2 seconds in Tr60. It is therefore advisable to install false ceilings in the classrooms to reduce their height.

-The results for speech clarity and intelligibility are influenced by high reverberation times; the presence of echo in the workshop thus leads to a decrease in clarity and intelligibility. Moreover, intelligibility is affected not only by high reverberation but also by background noise. Therefore, acoustic corrections using absorbent materials aim to reduce the reverberation time, and this reduction has allowed us to achieve optimal values for speech clarity and intelligibility.

-The acoustic correction of classrooms A and B began with the selection of durable acoustic panels that correspond to the reverberation time values across different frequencies. It is also important to place the panels on surfaces far from the sound source and receiving the late energy of the reverberant field. These relevant choices allowed for effective correction, and the simulated acoustic criteria results, including TR60, C50, and STI, were optimized.

V. Conslusion.

In conclusion, our study highlights the importance of coating materials and conceptual choices for the acoustic quality of classrooms. Numerical simulations allow us to predict this quality by integrating the performance of materials and modeling the spaces and sound sources. Our results emphasize the impact of room height on reverberation, with a recommendation to reduce this height to comply with standards. Furthermore, acoustic corrections using absorbent materials prove effective in improving speech clarity and intelligibility. Finally, the strategic placement of acoustic panels significantly contributes to the optimization of essential acoustic criteria for listening comfort and well-being in learning environments.

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