# A SURVEY OF THE UNOCCUPIED ACOUSTIC CONDITIONS OF ACTIVE LEARNING CLASSROOMS IN MONTREAL

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## Résumé

Les éducateurs ont mis au point des stratégies d'enseignement novatrices afin de maximiser les résultats d'apprentissage en classe. Les classes d'apprentissage actif constituent de nouveaux espaces pédagogiques qui facilitent ces stratégies grâce à un engagement accru des étudiants et à des discussions collaboratives. Les exigences acoustiques de ces classes n'ont toutefois pas encore été étudiées. Le présent article aborde par conséquent les conditions acoustiques des classes d'apprentissage actif situées à Montréal. Les paramètres acoustiques comme le bruit de fond, le temps de réverbération et l'indice de transmission de la parole dans des conditions de non-occupation sont examinés. Les résultats montrent que même si les classes sont nouvellement rénovées et conçues pour l'apprentissage actif, la majorité d'entre elles ne répondent pas aux exigences acoustiques standards pour ce qui est du temps de réverbération et du bruit de fond. Des études approfondies sur les conditions d'occupation des classes d'apprentissage actif pourront fournir une meilleure compréhension des exigences de conception acoustique de ces espaces.

**Mots clefs :** acoustique des salles de classe, intelligibilité de la parole, classe d'apprentissage actif

## Abstract

Educators have developed innovative teaching strategies in order to maximize learning outcomes in classrooms. Active learning classrooms are new learning spaces that facilitate teaching strategies with enhanced students' engagement and collaborative discussions. However, the acoustic requirements of the active learning classrooms have not been investigated yet. This paper presents, thus, the acoustic conditions of the active learning classrooms located in Montreal. The acoustical parameters such as background noise, reverberation time and speech transmission index in unoccupied conditions are examined. The results show that although all the classrooms are newly renovated and equipped to be used as active learning classrooms, the majority of them do not meet the standard acoustic requirements of the reverberation time and background noise level. Further studies on occupied conditions of active learning classrooms can provide a better understanding of the acoustical design requirements for these spaces.

**Keywords:** classroom acoustics, speech intelligibility, active learning classroom

## 1 Introduction

Students spend a considerable amount of time in classrooms where they acquire knowledge and skills to be integrated into society. Several factors contribute to learning efficiency and productivity. Environmental comfort analysis, therefore, is a multidisciplinary subject, which requires careful investigations by assorted research fields such as engineering, psychology, statistics, medicine, and educational science. A combination of measurements and questionnaires can provide a more comprehensive overview of environmental quality and occupants' well-being [1-3].

According to Astolfi and Pellerey [4], acoustical and visual qualities were perceived as the most important environmental factors influencing students' academic performance. Inappropriate acoustic characteristics of classrooms such as high background noise levels, long reverberation times and low signal-to-noise ratios (SNR) can affect stress, concentration, and academic performance of students in all different age groups [5]. These adverse effects are more detrimental for students with hearing impairment and second language learners [6-8].

Poor acoustic conditions do not only affect students. Teachers in noisy and reverberant classrooms also have to constantly raise their voices in order to communicate with the students. Exposure to these conditions over time leads to vocal fatigue, voice problems, increased level of stress and cognitive fatigue [9-11].

### Active learning classroom

Active learning approaches are based on students' engagement in the learning process. These methods lay more emphasis on developing students' skills rather than transmitting information through direct lectures. Chickering and Gamson [12] suggest that students not only need to listen but also write, read, discuss and participate in solving problems for better performance. The active learning is defined as "instructional activities involving students in doing things and thinking about what they are doing [13]".

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This new way of pedagogy leads to a new design of classrooms. Unlike traditional learning spaces for the lecture style, active learning classrooms need to provide space for more student-student interaction [14]. Figure 1 illustrates these active learning classrooms. The active learning inevitably generates noise by small group talks, movements, and electronics in use. The noisy classroom environment can become overwhelming to some students and can easily lead to distractions and off-task behaviours [15].

**Figure 1:** A typical active learning classroom at Dawson College in Montréal with flexible learning configuration

However, no specific acoustic guideline has been set to meet the special needs of such spaces up to this date. Therefore, this study focuses on the objective evaluation of the acoustic characteristics in the active learning classrooms.

## 2 Method

The acoustic characteristics of ten active learning classrooms in Montréal are investigated in this study. The classrooms are located in downtown Montreal at Concordia University and Dawson College. The brief descriptions of the ten classrooms are presented in Table 1.

Room impulses response was measured to calculate acoustical parameters such as reverberation time (T) and speech transmission index (STI) in these spaces with three different measurement configurations. The measurement configurations are determined by observing typical locations of students and teachers. The measurement system consists of a B&K omni-directional speaker and a class 1 sound level meter (Type 2250). The heights of the speaker and the receiver are 1.65 m and 1.1 m above the floor respectively.

All the classrooms are rectangular-shaped except the DW-3F38. The schematic plans of the measurement configurations are presented in Figure 2. The six measurement combinations for the three scenarios are investigated. For the first scenario, the speaker is located near the teacher's desk in the front of the classroom. In the second scenario, the speaker is located at the probable teacher's standing position in the middle of the classrooms. The last scenario is for between students' communication. The speaker is located at one of the students' desks in the middle of the classroom. For each scenario, the sound level meter is located at two different receiver positions where are the closest and farthest students' desk from the speaker. Background noise levels were measured for all the classrooms according to ANSI/ASA S16.60-2010/Part1 [16].

**Table 1:** Descriptions of the ten investigated active learning classrooms

| Name | Location | Volume ($m^3$) | Surface material |
|---|---|---|---|
| CO-CC10 | Concordia | 249 | ACT, cloth curtains, drywall |
| CO-FB11 | Concordia | 333 | ACT, carpets, drywall |
| DW-3F3 | Dawson | 208 | ACT, drywall, white boards |
| DW-3F5 | Dawson | 206 | ACT, drywall, white boards |
| DW-3F37 | Dawson | 212 | ACT, drywall, smart boards |
| DW-3F38 | Dawson | 222 | ACT, drywall, smart boards |
| DW-3F45 | Dawson | 182 | ACT, drywall, white boards |
| DW-3H10 | Dawson | 222 | ACT, drywall, smart boards |
| DW-7A2 | Dawson | 216 | ACT, drywall |
| DW-7A6 | Dawson | 237 | ACT, drywall |

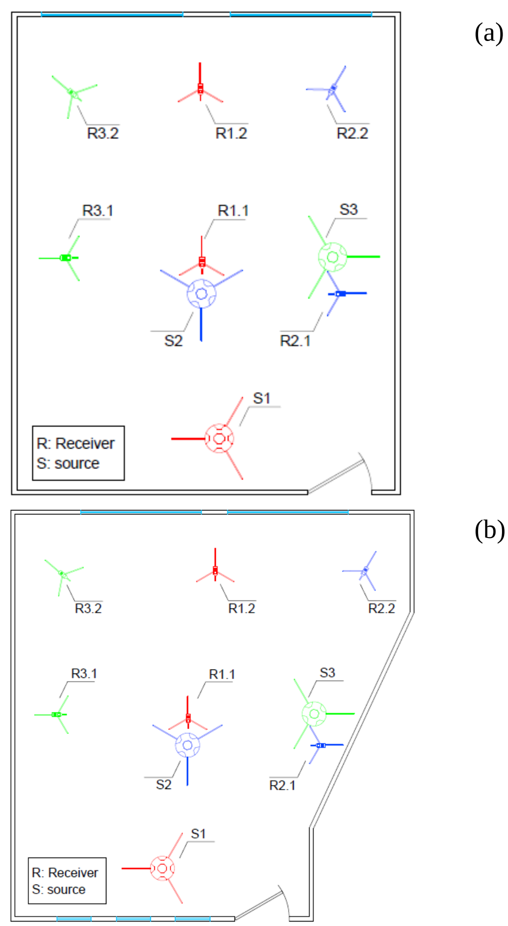


**Figure 2:** The schematic plan of measurement scenarios for (a) the nine measured classrooms except DW-3F38 and (b) DW-3F38

The measurements were taken while building mechanical system was running in the classrooms. Five consecutive 60-second measurements at the six locations in the classrooms were recorded and the A-weighted equivalent noise level ($L_{Aeq}$) is obtained by averaging the measured sound levels.

Room impulse responses were measured with a linear-sweep signal to calculate reverberation times and speech transmission index (STI) in the classrooms. The STI is calculated using the indirect method by deriving modulation transfer functions (MTF) from the impulse response [17]. The MDF depends on a signal-to-noise ratio (SNR) and room properties (e.g. reverberation time). The STI and reverberation time are obtained by averaging the results of the six measurement scenarios for each classroom.

## 3 Results & discussions

### 3.1 Room acoustics parameters

The measured acoustic parameters (T30, $L_{Aeq}$ and STI) of the classrooms are presented in Table 2.

The results of the middle frequency averaged reverberation times and their corresponding standard deviations are shown in Figure 3. According to ANSI/ASA S16.60-2010/Part1, the maximum reverberation time in the octave band frequencies of 500, 1000, and 2000 Hz should not exceed 0.5 seconds for space less than 283 $m^3$ and 0.6 seconds for space greater than 283 $m^3$. For the measured classrooms, the volume of all the rooms is less than 283 $m^3$ except for the CO-FB11. The low reverberation time in CO-FB11 is due to the acoustic treatment on the ceiling and floor with acoustic ceiling tiles and carpets. Figure 4 illustrates the spatial variations of the reverberation times in 6 different receiver locations. The results do not show any particular trend across different receiver locations for the reverberation time.

The results of the averaged A-weighted background noise levels for all the classrooms and their standard deviation are shown in Figure 5.

**Table 2:** The measured acoustic parameters of the active learning classrooms

| Classrooms | T30 [s] | $L_{Aeq}$ [dBA] | STI |
|---|---|---|---|
| CO-FB11 | 0.47 (±0.01) | 41 (±0.5) | 0.78 |
| CO-CC10 | 0.74 (±0.04) | 35 (±1.3) | 0.66 |
| Dw-3F3 | 0.67 (±0.07) | 53 (±6.2) | 0.7 |
| Dw-3F5 | 0.64 (±0.05) | 35 (±0.6) | 0.71 |
| DW-3F37 | 0.64 (±0.07) | 49 (±3.4) | 0.69 |
| DW-3F38 | 0.62(±0.07) | 54 (±6.2) | 0.68 |
| DW-3F45 | 0.57 (±0.06) | 54 (±7.0) | 0.74 |
| DW-3H10 | 0.57 (±0.08) | 56 (±5.0) | 0.73 |
| DW-7A2 | 0.55 (±0.02) | 43(±3.9) | 0.74 |
| DW-7A6 | 0.61 (±0.05) | 53 (±6.9) | 0.72 |

According to the ANSI/ASA S16.60-2010/Part1, the background noise level should not exceed 35 dBA for core learning spaces. The results show that only CO-CC10 and DW-3F5 meet the criteria for the background noise level. It is expected that all the classrooms have higher background noise levels during regular school time.

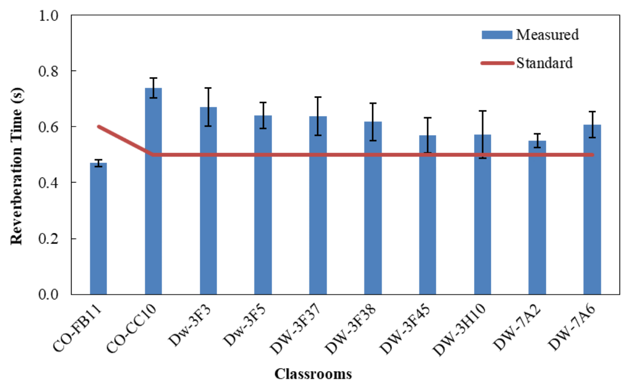


**Figure 3:** The middle-frequency averaged reverberation times (T30) in the active learning classrooms

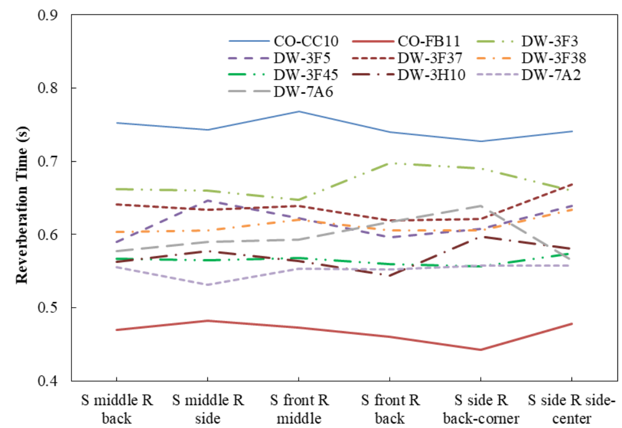


**Figure 4:** The middle-frequency averaged reverberation times (T30) in the classroom for the six measurement locations

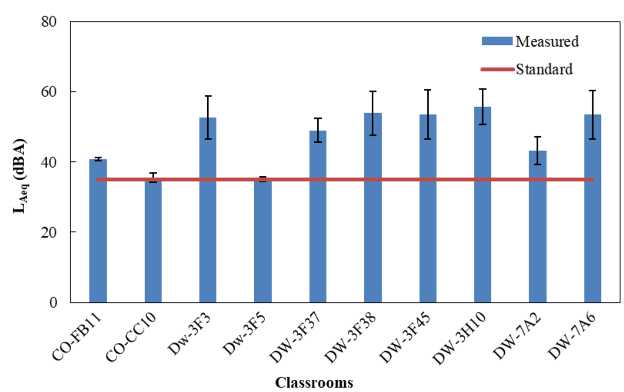


**Figure 5:** The averaged A-weighted background noise levels for the classrooms and the corresponding standard deviations

## 3.2 Speech intelligibility in the classrooms

The Speech Transmission Index (STI) for each space was calculated with the measured impulse responses. According to the STI qualification ratings from ISO 9921 [18], four speech transmission index values of 0.2, 0.4, 0.6 and 0.8 correspond respectively to ‘‘Bad”, “Poor”, ‘‘Good” and ‘‘Excellent” speech intelligibility conditions. The STI is also calculated through the fast estimation method proposed by Nowoświat and Olechowska [19]. They introduced a function for fast estimation of STI with a reverberation time value only. The fast estimation equation for STI is expressed as:

$$STI = A \ln T + B, \quad (1)$$

Where A = -0.2078, B = 0.6488 and T = the averaged reverberation time of mid-frequency octave bands of 500, 1000 and 2000 Hz. The results of the measured STI and calculated STI together with their corresponding speech intelligibility ratings are represented in Table 3.

The calculated STIs based on equation (1) show good agreement with the measured values. CO-CC10 has the lowest STI value among all the classrooms mainly due to its high reverberation time and CO-FB11 has the highest STI with the shortest reverberation time, which confirm the adverse effect of reverberation times on speech intelligibility.

It is noteworthy that the STI ratings show “good” and “excellent” condition for speech intelligibility of the classrooms although only one of the classrooms met the suggested criteria for reverberation time and background noise level.

The proximity of the measured and estimated STI values suggests that the measured STI follows a linear relation with reverberation time values. Correlation between measured STI and measured T30 and $L_{Aeq}$ values are illustrated in Figure 6. The coefficient of correlation ($R^2$) between T30 and STI is equal to 0.87 and statistically significant. The coefficient of correlation ($R^2$) between measured STI and $L_{Aeq}$ is 0.0032, which confirms the negligible effect of the background noise level in calculating STI in this study. The results are aligned with the Nowoświat and Olechowska’s findings [19] based on the measured and estimated STIs.

To investigate the correlation between STI values and combined metrics of the A-weighted background sound pressure level (SPL) and reverberation time, the best fitted-surface for the measured STI with SPL and T30 values is illustrated in Figure 7. The best STI rating can be obtained when the reverberation time has the minimum acceptable values and the results show the importance of low reverberation time to maintain the speech intelligibility in classrooms in a desirable range. By increasing background noise level with a constant reverberation time, no specific change in STI values is observed, which is aligned with the previously mentioned assumption about the negligible effect of the background noise level in calculating STI values.

**Table 3:** The measured STI, estimated STI and their corresponding speech intelligibility ratings of the active learning classrooms

| | Measured | Estimated | Rating |
|---|---|---|---|
| CO-FB11 | 0.78 | 0.81 | Excellent |
| CO-CC10 | 0.66 | 0.71 | Good |
| DW-3F3 | 0.70 | 0.73 | Good |
| DW-3F5 | 0.71 | 0.74 | Good |
| DW-3F37 | 0.69 | 0.74 | Good |
| DW-3F38 | 0.68 | 0.75 | Good |
| DW-3F45 | 0.74 | 0.77 | Good |
| DW-3H10 | 0.73 | 0.77 | Good |
| DW-7A2 | 0.74 | 0.77 | Good |
| DW-7A6 | 0.72 | 0.75 | Good |

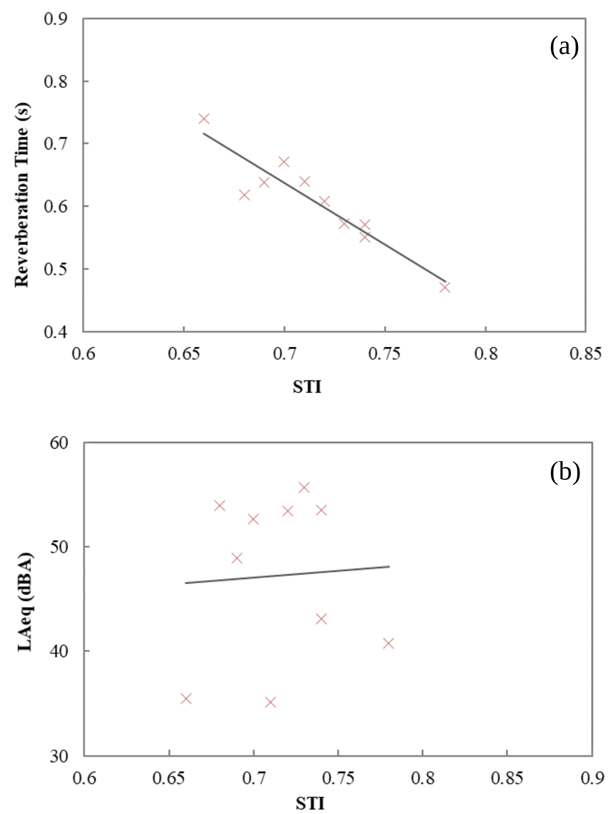


**Figure 6:** Relationship between STI and (a) the averaged reverberation time (T30) of 500, 1k and 2k Hz octave bands and (b) the background noise level.

# 4 Conclusion

A survey on the acoustic condition of 10 active learning classrooms has been carried out. All the classrooms are recently renovated and equipped to be used as active learning environments. All of them are finished with acoustic ceiling tiles while COFB-11 is also treated with carpets to increase the acoustic absorption.

The measurements were done in unoccupied conditions during summer time while HVAC was running. The background noise level is obtained by averaging the five 60 seconds measured A-weighted sound levels in the six key locations for each classroom.

It is observed that only two classrooms meet the standard requirements of 35 dBA for averaged A-weighted background noise level. Since all these measurements took place after official schools' hours, it is also expected that the occupied background noise level is higher for the classrooms. Among all the measured classrooms, only CO-FB11, which is treated with both ACTs and carpet, meets the standard requirement for the reverberation time of 0.5 s. Speech intelligibility is also evaluated for the classrooms using measured STI by means of the impulse response method. The STI was also calculated using a fast method proposed by Nowoświat and Olechowska [19]. The correlation between STI and combined metrics of SPL and RT follows the expected trend as indicated in previous studies.

Further research needs to be done in order to evaluate the acoustic conditions of occupied classrooms and investigate the correlation between unoccupied and occupied acoustic parameters in these spaces. The result of objective acoustic surveys of occupied and unoccupied conditions of active learning classrooms, combined with subjective studies on students and teachers' perception of acoustic comfort in such spaces can lead to the better understanding of specific design requirements of these new learning spaces.

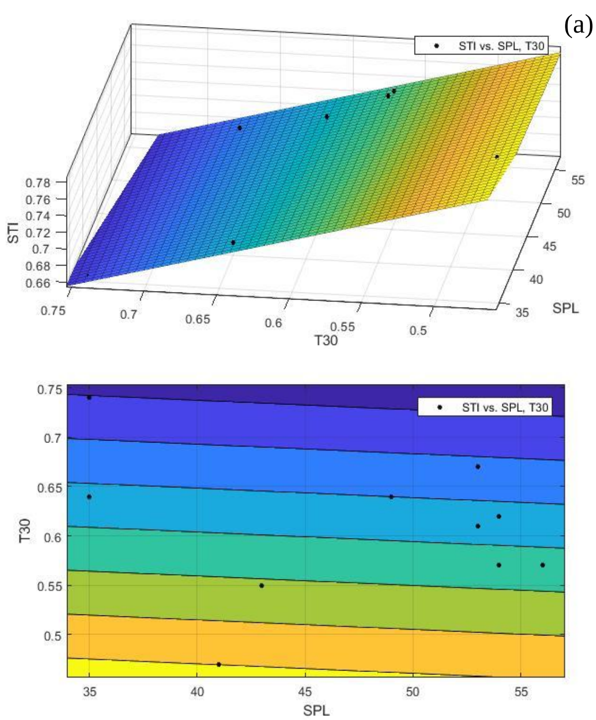


**Figure 7: (**a) 3D plot and (b) contour plot to illustrate the correlation between STI and combined metrics of SPL and reverberation time.

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