DOI: 10.61782/fa.2025.0148

FORUM ACUSTICUM EURONOISE 2025

ASSESSING SOUND LEVELS OF STUDENT ACTIVITY IN PRIMARY SCHOOL CLASSROOMS

Chiara Visentin[1*] **Nicola Prodi**[1]
[1] Department of Engineering, University of Ferrara, Italy

ABSTRACT

Student activity noise is the dominant sound source in primary school learning environments. While this noise reflects the dynamic and interactive behavior of young learners, and can potentially enhance social interactions and peer learning, it can also become overwhelming, disrupting the perception of the teacher's message and negatively affecting students' well-being and concentration. The levels of student activity noise in the classroom may vary based on several factors, including students' age, acoustic characteristics of the room, and the type of lesson.
This study investigates how student activity levels and the signal-to-noise ratio change according to these factors, aiming to establish a relationship between classroom acoustics and the dynamic behaviour of its occupants. Active lessons were monitored in five primary schools in Ferrara and Padova, Italy, involving over twenty-five classes. Sound levels in occupied classrooms were analyzed using Gaussian Mixture Models to divide between teacher's speech and student activity levels. The findings of this study aim to clarify the connection between lesson types and room acoustic parameters for different students' ages, with the goal of informing the design of more effective learning environments.

Keywords: *classroom acoustics, student activity, noise*

1. INTRODUCTION

Classroom acoustics play a crucial role in shaping the learning environment. This is particularly true in primary classrooms as young students are still developing their cognitive, linguistic, and auditory skills. Good acoustic conditions are required to ensure near ceiling intelligibility [1], good comprehension of the teacher's and peers' message, and reduced listening effort and fatigue [2]. All these aspects are central in promoting an engaging and motivating learning environment and a positive school climate [3]. However, classrooms often suffer from excessive reverberation and noise levels, that negatively affect the teacher vocal effort and teaching style [4], and students' performance and well-being [5].
One of the primary sources of noise in classrooms is student activity itself, that is the mix of voices and movements of the students [6]. In primary classrooms, where interactive and participatory learning methods are increasingly used, noise levels can change significantly depending on the type of activity, and the number of students, besides students' age. However, such data are surprisingly scarce. Two recent studies measured overall sound pressure levels (SPL) in classrooms during various lesson types and correlated them with students' subjective perception of annoyance of listening effort [7, 8]. However, speech and activity sounds were analyzed together rather than separately. In contrast, Wang and Brill [9] conducted an extensive survey of occupied K-12 classrooms, distinguishing SPLs of target speech from activity sounds, but did not address changes in the type of activity. A survey in Korean schools addressed the relationship between student activity levels and classroom activity but exploring a wider range of students age (from primary school to university) [10].
Therefore, to address this literature gap, this study aimed to investigate how student activity levels and signal-to-noise ratio change according to students age, the type of classroom activity, and classroom acoustics. The final goal

[*] ***Corresponding author***: *chiara.visentin@unife.it*

is to establish a relationship between classroom acoustics and the dynamic behavior of its occupants.

2. MATERIALS AND METHODS

2.1 Schools and classrooms

Five primary schools in Ferrara and Padova (Italy) were involved in the study conducted during spring and autumn 2024. The schools included students from diverse socio-economic backgrounds, ensuring a representative sample across different income levels and social contexts. Within each school, classes were recruited on a voluntary basis resulting in a total number of 26 classes distributed from grade II to V.
In each classroom, acoustic measurements were performed in unoccupied conditions outside school hours. Furthermore, sound levels were monitored continuously over a school day, with the students in the classroom performing regular lessons.

2.2 Acoustic characterization of the classrooms

In each classroom, acoustic measurements were performed in unoccupied conditions outside school hours, according to the Italian standard on classroom acoustics UNI 11532-2 and the standard ISO 3382-2. Impulse responses were obtained with a sine-sweep technique and used to calculate reverberation time (T_{30}) and speech clarity (C_{50}) as the spatial average of the source-receiver combinations. The reverberation time measured in unoccupied conditions was corrected to consider an 80% occupancy and compared to the optimal range defined in the UNI 11532-2, referring to category A3 (classrooms). For speech clarity it was defined one source positions (close to the desk or the whiteboard, were the teacher usually stands while doing lessons), and four receivers in the area where students sit. The background noise level (A-weighted, equivalent level, L_{anb}) was measured with the door and the windows closed in the most unfavourable positions (the one closer to a background noise source).
The results indicate that in 23 out of 26 classrooms, T_{30} was higher than the reference range (frequency interval 125-4000 Hz) and C_{50} was lower than the reference value of 2 dB. The three classrooms complying with the standards were acoustically treated with a sound absorbing ceiling. Background noise (composed by sounds from the outdoors and the HVAC system) was lower than the reference value of 38 dB(A) in 19 out of 26 classrooms.

2.3 Sound level monitoring

Equivalent sound levels were monitored during one school day (5 to 8 hours) in each classroom, thus including different lesson types for each class. Lesson types were categorized following Shield and Dockrell [11] and Radun et al. [7] as: silent work, frontal lesson and group activity. Classroom observations were conducted during monitoring to note down the type of activity and unexpected events.
Speech and noise levels were measured using a sound level meter (DUO, 01 dB) at one receiver position in the back of the classroom, close to the last row of desks, at a height of 1.2 m. The levels were monitored every 100 ms to ensure the recording of the pauses among syllables and words [12].

2.4 Speech and noise levels analysis

The recorded lessons were analysed and divided in time slots of 20 minutes. The duration of the slot is determined by the need to structure lesson periods around a similar activity (which is particularly challenging for lower grade levels) and to ensure stability in the results obtained through the analysis algorithm. Data were indeed analyzed via Gaussian Mixture Modelling (GMM [13]), an unsupervised statistical learning technique that was applied to the logged equivalent levels to categorize data into two clusters corresponding to teacher's speech and student activity noise. Previous literature studies on both primary schools and university classrooms demonstrated that this technique can successfully identify speech and noise levels during active lessons [9, 14, 10].

3. RESULTS AND DISCUSSION

Figure 1 shows an example of a distribution of A-weighted equivalent sound levels measured during a 20-minute slot of frontal lesson in a grade II classroom. The calculated density function (solid line) is left-skewed, suggesting that the distribution can be split into two separate distributions corresponding to the levels of the teacher's voice and the levels of the students' activity.
All monitored lessons were analyzed via GMM, to obtain the speech levels, noise levels and speech-to-noise ratio in each classroom and for each type of activity. Figure 2 shows a comparison between the noise levels calculated in grade II and grade V. The results are highly dispersed, even within the same type of activity and for each grade. This variability is partly due to the acoustic characteristics of the classrooms, but also to the teacher conducting the lesson and the specific type of lesson delivered. For example, even in the case of a frontal

lesson, the level of interaction between teacher and students could greatly vary depending on the topic and the teacher's didactic approach.

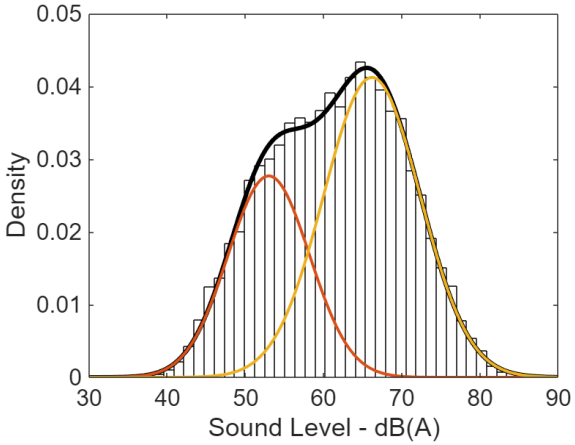

Figure 1. Fitting of the two Gaussian distributions (right: speech; left: student activity) to match the frequency distribution of sound levels at the receiver position.

Preliminary statistical analyses were performed using multiple linear regressions with type of activity, grade, acoustic parameters (T30 and C50) as independent variables. The statistical model with speech level as dependent variable indicates a significant effect of the grade (p = 0.040) and the type of activity (p = 0.023). Classroom acoustic parameters had no significant effect. In particular, the speech level was higher in frontal lesson and group work compared to individual work (mean difference: 2.5 dB), and in grade II and IV compared to grade V (mean difference: 2.7 dB). The model with noise level as dependent variable showed a significant effect of grade (p =0.048) and C50 (p = 0.003). Specifically, student activity levels were higher in grade II compared to grade III and grade V (mean difference: 3.3 dB). Furthermore, noise levels were found to have a negative relationship with speech clarity, with an estimated decrease of 1.8 dB for every 1 dB increase in C50.

Overall, speech and noise levels varied over a wide range, from 52 to 73 dB(A) and from 39 to 60 dB(A). The mean value of student activity was 50 dB(A) (SD=4.6 dB(A)), which is in line with the background noise levels measured in Canadian elementary schools (mean value: 49.1 dB(A) [15]). The value is slightly lower than the noise level measured in Korean elementary schools (55.5 dB(A) [10]) substantially greater than the value of 35 dB(A) recommended by the World Health Organization in active classrooms.

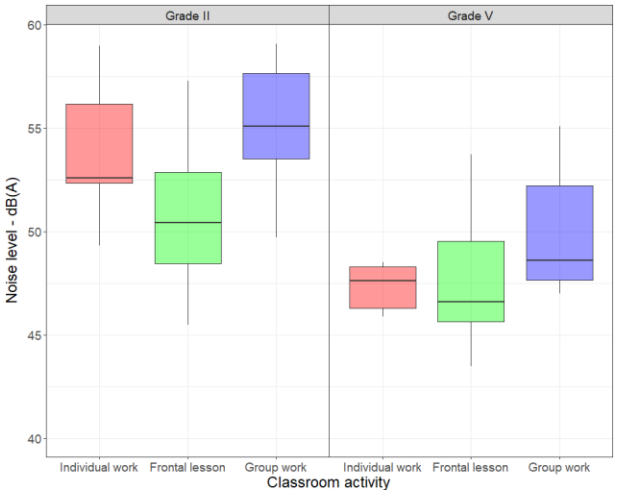

Figure 2. Boxplots of student activity noise levels estimated using GMM, categorized by grade (Grades II and V) and classroom activity. Each dot in the graph represents a class.

4. CONLCUSIONS

The study focuses on the relationship between classroom acoustics, speech, and noise levels, considering the role of students' age and type of activity. Data from the monitoring of a large set of lessons in different primary schools were analyzed using Gaussian Mixture Models to obtain the speech and student activity noise levels. Statistical analyses were performed by using multiple regression models.

Excessive noise levels were found in all the active classrooms, always greater than the reference value of 35 dB(A) set by the WHO. The mean SNR value was 12.6 dB, slightly lower than the suggested value of +15 dB necessary for primary school children to get near perfect intelligibility [16]. It should be noted that the recommended value increases up to +20 dB for the youngest students (6–7-year-olds) and for classrooms with children with hearing or language impairment.

Preliminary analyses suggest that both noise and speech levels tend to consistently decrease with age, irrespective of the type of activity. The type of activity in the classroom seems to be significant only with respect to the speech level

while no difference was found in the noise level of the students. Further statistical analyses are required to control for the spread of speech and noise level.

5. ACKNOWLEDGMENTS

This research was funded by the Italian Ministry of University and Research (MUR) under the PRIN project "LearN – Learning in Noise".

6. REFERENCES

[1] S. Murgia, J. Webster, L. C. C. Cutiva and P. Bottalico: "Systematic review of literature on speech intelligibility and classroom acoustics in elementary schools," *Language, speech, and hearing services in schools*, vol. 54, no. 1, pp. 322-335, 2023.

[2] N. Prodi and C. Visentin: "A slight increase in reverberation time in the classroom affects performance and behavioral listening effort," *Ear and Hearing*, vol. 43, no. 2, pp. 460-476, 2022.

[3] M. T. Wang and J. L. Degol: "School climate: A review of the construct, measurement, and impact on student outcomes," *Educational psychology review*, vol. 28, no. 2, pp. 315-352, 2016.

[4] E. Hytonen-Ng, K. Pihlainen, K. Ng and E. Karna: "Sounds of learning: Soundscapes-teacher perceptions of acoustic environments in Finland's open plan classrooms," *Issues in Educational Research*, vol. 32, no. 4, pp. 1421-1440, 2022.

[5] A. Astolfi, G. E. Puglisi, S. Murgia, G. Minelli, F. Pellerey, A. Prato and T. Sacco: "Influence of classroom acoustics on noise disturbance and well-being for first graders," *Frontiers in Psychology*, vol. 10, 2736, 2019.

[6] M. Hodgson, R. Rempel and S. Kennedy: "Measurement and prediction of typical speech and background-noise levels in university classrooms during lectures," *The Journal of the Acoustical Society of America*, vol. 105, no. 1, pp. 226-233, 1999.

[7] J. Radun, M. Lindberg, A. Lahti, M. Veermans, R. Alakoivu and V. Hongisto: "Pupils' experience of noise in two acoustically different classrooms," *Facilities*, vol. 41, no. 15/16, pp. 21-37, 2023.

[8] J. Seitz and J. Fels: "Activity-based acoustic situations in primary schools: Analyzing classroom noise and listening effort," *The Journal of the Acoustical Society of America*, vol. 157, no. 3, pp. 1772-1783, 2025.

[9] L. M. Wang and L. C. Brill: "Speech and noise levels measured in occupied K–12 classrooms," *The Journal of the Acoustical Society of America*, vol. 150, no. 2, pp. 864-877, 2021.

[10] Y. J. Choi: "An acoustic survey of Korean school classrooms: The necessity for Korean acoustic standards and design guideleines," *Applied Acoustics*, vol. 231, 110548, 2025.

[11] B. Shield and J. E. Dockrell: "External and internal noise surveys of London primary schools," *The Journal of the Acoustical Society of America*, vol. 115, no. 2, pp. 730-738, 2004.

[12] D. D'Orazio, D. De Salvio, L. Anderlucci, and M. Garai: "Measuring the speech level and the student activity in lecture halls: Visual-vs blind-segmentation methods," *Applied Acoustics*, vol. 169, 107448, 2020.

[13] G. J. McLachlan and K. E. Basford: *Mixture models: Inference and applications to clustering (Vol. 38)*. New York: M. Dekker, 1988.

[14] D. De Salvio and D. D'Orazio: "Effectiveness of acoustic treatments and PA redesign by means of student activity and speech levels," *Applied Acoustics*, vol. 194, 108783, 2022.

[15] H. Sato, and J. S. Bradley: "Evaluation of acoustical conditions for speech communication in working elementary school classrooms," *The Journal of the Acoustical Society of America*, vol. 123, no. 4, pp. 2064-2077, 2008.

[16] K. Mealings, "Classroom acoustic conditions: Understanding what is suitable through a review of national and international standards, recommendations, and live classroom measurements," in *Proc. of Acoustics 2016* (Brisbane, Australia), 2016.