DOI: 10.61782/fa.2025.0506

FORUM ACUSTICUM
EURONOISE 2025

INVESTIGATION ON THE ACOUSTIC CONDITIONS OF ACTIVE CLASSROOMS IN ACCORDANCE WITH THE STUDENTS AND CLASSROOM ACTIVITIES

Young-Ji Choi[1]
[1] Department of Architectural Engineering, Kangwon National University, Korea

ABSTRACT

The present study investigates the acoustic conditions of active classrooms based on the speech and noise levels. The speech and noise levels were measured in 29 classrooms during 57 actual classes in Korean schools. The effects of occupants and classroom activities on the speech and noise levels in occupied classrooms were examined. The present results indicate a general trend of decreasing noise levels by 6 to 12 dBA with increasing age of the students. Additionally, the noise levels in the classrooms were found to be closely related to the type of classroom activities. The results indicate that the acoustic standards should recommend reducing the unoccupied noise levels in order to minimize noise levels in active classrooms.

Keywords: *acoustic conditions, active classrooms, classroom activities, speech-to-noise levels.*

1. INTRODUCTION

Key acoustic parameters in the acoustic design of school classrooms are categorized as the background noise, reverberation time, and sound insulation performance, all of which are evaluated based on the standards for unoccupied conditions [1-2]. While the acoustic conditions of unoccupied rooms are crucial for ensuring appropriate speech intelligibility in actual learning environments, occupied acoustic conditions vary depending on the presence of occupants and the nature of classroom activities. Based on findings from on-site measurements conducted in various domestic and international classrooms, the acoustic conditions in learning environments vary significantly between unoccupied and occupied rooms [3-9]. Notably, the increase in background noise caused by occupants and classroom activities contributes to a reduction in the signal-to-noise ratio (SNR), which serves as a critical factor for achieving high speech intelligibility [3-9]. Thus, to enhance learning outcomes in school classrooms, it is essential to establish acoustic standards and designs that incorporate occupied acoustic conditions—reflecting influential factors such as presence of the occupants and classroom activities—based on the acoustic parameters of unoccupied spaces.

This study aims to investigate the acoustic conditions in learning environments across elementary, junior high, high, and special schools as well as university classrooms in Korea. Measurements were conducted in 14 classrooms and 15 lecture rooms during actual classes, focusing on speech and noise levels across a total of 57 instructional settings. The study analyzes the acoustic environment based on occupancy and the type of learning activities, providing insights into the conditions required to achieve optimal speech intelligibility in classrooms and lecture rooms. The findings, derived from on-site measurements, serve as a basis for improving the acoustic standards of domestic educational spaces.

2. MEASUREMENT IN ACTIVE CLASSROOMS

The classrooms were classified by learning age groups, and measurements were carried out over the period from 2017 to 2023. International standards for classroom acoustic performance [1-2] are defined based on either volume or learning activities, and as such, spaces with volumes under 283m³ and those primarily used for core-learning spaces were selected.

The mean volume of 14 classrooms in elementary, junior high, high, and special schools ranged from 122m³ to 169m³, with special school classrooms having the smallest volumes. This difference is attributed to the number of

*Corresponding author: youngjichoi@kangwon.ac.kr.

students per class; while the average occupancy of general school classrooms was 27 individuals (σ = 3.2), special school classrooms had an average of only 5 occupants (σ = 1.5), representing approximately five times the difference. The mean volume of 30 university lecture rooms ranged from 247 m³ to 257 m³, with average occupancy rates ranging from 22 to 41 individuals, reflecting a seating utilization rate of approximately 50–65%. University classrooms were measured before and after the pandemic in 2017 and 2022, respectively, with the 50% occupancy rate being influenced by social distancing measures during the pandemic.

In classroom and lecture hall settings, learning activities are primarily categorized into plenary sessions, group work, individual work, and activities utilizing audiovisual materials. Depending on the context, these approaches may be conducted independently or in combination.

In elementary, junior high, high schools, and special schools, classes were conducted either in a single activity format or combining three activities concurrently. In contrast, university classes were predominantly conducted in single activity formats. Depending on the students' ages, class durations varied between 40 to 50 minutes.

Two to four sound level meters (Tango Plus, Sinus) were placed at a height of 1.2 m, corresponding approximately to the ear level of students seated in the front and rear seats of the classroom. This location is about 2 to 8 m from where the teacher stands. The measurement of speech and noise levels was carried out for the duration of approximately 40 to 50 minutes of class time, where the teacher's voice served as the primary sound source within the classroom. These measurements spanned both pre-pandemic and post-pandemic periods, during which the ratio of teachers wearing masks varied significantly across spatial settings, ranging from 0% to 100%.

3. COMPARISONS OF SPEECH AND NOISE LEVELS BASED ON STUDENT AGE AND CLASSROOM ACTIVITIES

Table 1 presents the average speech levels, noise levels, and SNR values, along with their standard deviations (σ), recorded at 57 classroom settings across 29 elementary, junior high, high and special schools, as well as universities in Korea, categorized by student age groups. As the age of students increases, noise levels in classroom environments tend to decrease, with differences of approximately 6 to 12 dBA observed between elementary school students and middle/high school or university students. Similarly, the mean speech levels of talkers in classroom settings varied significantly by age group, ranging from approximately 55 to 68.5 dBA. The younger the students, the higher the speech levels recorded, with a notable difference of around 13.5 dBA between adult university students and elementary school students. This difference can be attributed to variations in teaching methods, as younger students are often engaged in diverse activities to encourage participation, compared to the lecture-based format predominantly used in universities. In particular, elementary school classrooms displayed a strong correlation between noise levels and the types of learning activities conducted, aligning with findings from previous studies [4].

Table 1. Mean and standard deviations (σ) of speech levels, noise levels, and speech to noise ratios averaged over 57 active classes.

Age	Speech levels, dBA	Noise levels, dBA	SNR, dBA
8-10	68.5 (σ=6.0)	54.9 (σ=6.6)	13.6 (σ=3.5)
12-15	64.1 (σ=4.6)	48.6 (σ=5.4)	15.5 (σ=3.3)
21-27	54.9 (σ=5.4)	42.4 (σ=3.8)	12.5 (σ=3.8)
20-25	57.2 (σ=2.9)	48.8 (σ=2.1)	8.4 (σ=2.7)

Results from Table 1 indicate some variation in measurements from university lecture rooms, which were conducted both before and after the pandemic. These differences are presumed to be influenced by variables affecting the acoustic conditions within the lecture halls, such as the number of occupants and the talker's use of a mask. Notably, during the pandemic period, despite speech levels being approximately 2 dBA lower due to mask usage by the talker, reduced occupant numbers led to lower noise levels, resulting in an approximately 4 dBA higher SNR value. The proportion of learning environments with speech levels exceeding 65 dBA was 66.7%, 38.1%, and 0% for elementary, middle/high school, and university classrooms, respectively, demonstrating a decrease in speech levels as student age increased. Similar trends were observed in noise levels. The difference in noise levels between unoccupied and occupied classrooms was more pronounced in settings with younger students, with a gap of approximately 15 dBA. The proportion of classrooms with noise levels exceeding 50 dBA was 83.3%, 38.1%, and 0% across the three age

groups, respectively, influencing the overall SNR values. For students aged 8–10 years, only 33.3% of classrooms achieved SNR values of 15 dBA or higher.

Table 2. Mean and standard deviations (σ) of speech levels, noise levels, and speech to noise ratios averaged over 27 active classes in elementary, junior high, high and special schools for different classroom activities.

Teaching activities	Speech levels, dBA	Noise levels, dBA	SNR, dBA
Plenary	65.1 (σ=4.5)	49.4 (σ=5.1)	15.7 (σ=3.3)
Group work	73.2 (σ=3.9)	62.9 (σ=6.0)	10.3 (σ=2.1)
Individual work	57.8 (σ=4.8)	44.2 (σ=3.7)	13.7 (σ=1.1)
Watching video	54.4 (σ=5.2)	50.0 (σ=1.8)	14.4 (σ=3.4)

As shown in the results of Table 2, higher noise levels were observed in elementary, junior high, and high school classrooms in Korea when classes incorporated discussions and group activities. The noise levels during classes appeared to vary according to the characteristics of the teaching activities. For example, in elementary school, the noise level differed by approximately 19 dBA between lessons without group activities (48 dBA) and those that included them (67 dBA). Similarly, in junior high school, classes involving group activities showed noise levels approximately 10 dBA higher, reflecting a pattern comparable to that of elementary schools. Classes that incorporated audiovisual materials exhibited noise levels similar to or slightly lower than other classes. The lowest noise levels (44 dBA) were recorded during individual activities such as examinations, reading, and self-study.

Changes in noise levels associated with teaching activities in Korean elementary schools were found to be similar to those observed in elementary schools in the United Kingdom [4]. In the UK, the minimum and maximum noise levels during lessons across six different types of teaching activities were recorded at 56 dBL_{Aeq} and 77 dBL_{Aeq}, respectively, demonstrating a close relationship between teaching activity types and noise levels.

Figure 1 illustrates the noise levels recorded in 57 active classes, focusing on the relationship between speech levels and noise levels. The mean speech and noise levels experienced by students at their seats were represented using different symbols based on age. These values represent the average from 2–4 measurement positions within each classroom. As previously mentioned in the results of Tables 1 and 2, the speech and noise levels in classrooms were found to be influenced by the occupants' age and the type of classroom activities conducted. The correlation between speech and noise levels was analyzed and included in Figure 1.

As shown in Figure 1, the mean noise level in 30 university classrooms was approximately 37–51 dBA, which is about 4 dBA lower than the minimum noise levels recorded during quiet activities such as reading, self-study, or exams in high school classrooms. Compared to junior high and high schools, noise levels in elementary school classrooms were about 6–8 dBA higher. Group activities produced the highest noise levels across age groups, highlighting the impact of not only age but also the nature of teaching activities on classroom noise levels. The results of this study align closely with findings observed in elementary and high school classrooms in the United Kingdom and Canada, where noise levels similarly showed significant variation based on classroom activities [4-6].

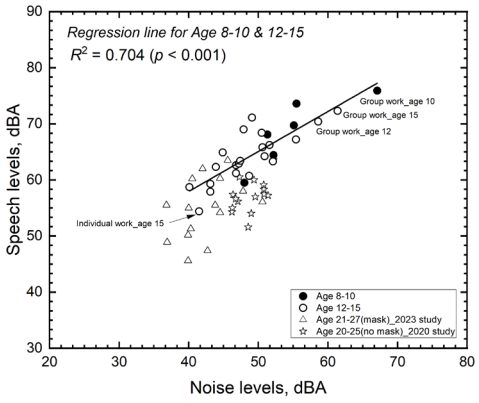

Figure 1. Mean speech level versus noise levels in 57 active classes.

In particular, a significant linear correlation (R^2 = 0.704, p < 0.001) was observed between speech levels and noise levels in 27 classrooms across elementary, junior high, and high schools, as well as special schools. This correlation indicates that as noise levels increase, speech levels also rise correspondingly. Based on the linear correlation equation (y = 0.71x + 29.45), it was found that for every 1 dBA increase in classroom noise levels due to teaching activities,

the speech levels of teachers increased by approximately 0.71 dBA. Such significant linear correlations were not observed in 30 university lecture settings. This discrepancy is likely attributable to differences in teaching methods across age groups.

4. COMPARISONS WITH OCCUPIED SPEECH AND NOISE LEVELS IN OTHER COUNTIRES

Studies conducted in elementary and high schools in the UK [4, 6] reveal that the average voice level during typical classroom activities is approximately 65 dB L_{Aeq}, which aligns closely with measurements taken in 27 classroom settings across domestic elementary, middle, high, and special schools (65.1 dBA). Similarly, findings from 29 elementary school classrooms in Finland indicate an average voice level of 69 dB L_{Aeq}, comparable to results observed in domestic elementary schools (68.5 dBA) [8]. However, the average noise level in Finland was approximately 42 dB L_{A90}, which is 13 dBA lower than domestic classrooms. This discrepancy is attributed to relatively quieter ambient noise levels (34.5 dBA with HVAC systems operating). Finnish studies also reported a significant linear correlation between noise levels during class and ambient noise levels, with similar observations documented in the UK high school acoustic surveys [6]. Korean classrooms exhibited higher average ambient noise levels at 43.8 dBA (σ = 3.0) compared to Finnish elementary schools, which likely influenced the acoustic conditions during classroom occupancy. However, ambient noise levels were not measured in all classrooms, limiting the analysis of correlations with noise levels during occupancy.

Meanwhile, Canadian elementary school measurements reported voice and noise levels (60.1 dBA, 49.1 dBA) that were respectively 9 dBA and 6 dBA higher than Korean classroom levels. These results may have been influenced by measurement periods limited to approximately 15–20 minutes during which teachers primarily conducted lessons while students listened quietly [5]. The mean speech and noise levels during Canadian elementary school classes were similar to those observed in the quietest Korean classroom environments (speech level: 59.5 dBA, noise level: 48 dBA).

In Italian high schools, noise levels across six classrooms ranged from 46.5–52.1 dB L_{Aeq}, exhibiting smaller variation compared to measurements taken in 11 domestic high school classrooms (41.5–61.4 dBA) [7]. Additionally, significant correlations were observed between reverberation time and noise levels during occupancy, a finding consistent with measurements from Korean university classrooms. Reverberation time and noise levels were strongly correlated with speech intelligibility metrics, emphasizing the necessity of measuring acoustic parameters in occupied conditions [10].

5. CONCLUSIONS

This study investigated and analyzed the acoustic conditions of occupied classrooms in Korean educational facilities based on voice and noise levels measured during actual classes. Measurements were conducted in 57 classrooms and lecture rooms across 29 elementary, junior high, high, special schools as well as universities. Results indicated that acoustic conditions during classes were influenced by variables such as the number and age of occupants, with speech and noise levels increasing as the number and age of occupants rose. These findings align with previous research [4-6].

However, due to practical limitations inherent in field measurements, the study was unable to analyze the specific effects of various lesson and learning activities in detail, highlighting a limitation of this research.

To ensure high speech intelligibility in actual classroom and lecture hall settings, it is essential to minimize unoccupied ambient noise levels to an appropriate standard (below 37 dBA under HVAC operation conditions). The acoustic conditions during unoccupied conditions are crucial for achieving an optimal signal-to-noise ratio (SNR). For the improvement of acoustic conditions in Korean educational facilities, it is imperative to establish currently absent acoustic standards for such facilities [11]. Further research should include parallel measurements of acoustic parameters during occupancy to enable comparative analyses of unoccupied and occupied acoustic conditions.

6. ACKNOWLEDGMENTS

I am very grateful to the students of the department of Architectural Engineering at Kangwon National University and the schools, students, and teachers who have participated in the measurements. This work was supported by National Research Foundation of Korea Grant funded by the Korean Government (2021R1A2C1004449, RS-2025-00513065).

7. REFERENCES

[1] ANSI/ASA 12.60-2010/Part1, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools: Part 1. Permanent Schools, 2010.

[2] Building Bulletin 93, Acoustic Design of Schools: Performance Standards, 2015.

[3] M. Hodgson, R. Rempel, and S.Kennedy, "Measurement and prediction of typical speech and background noise levels in university classrooms during lectures," *J. Acoust. Soc. Am.* vol.105, no.1, pp.226-233, 1999.

[4] B. Shield, and J. Dockrell, "External and internal noise surveys of London primary schools," *J. Acoust. Soc. Am.* vol. 115, no.2, pp.730–738, 2004.

[5] H. Sato and J. S. Bradley, "Evaluation of acoustical conditions for speech communication in working elementary school classrooms," *J. Acoust. Soc. Am.* vol.123, no.4, pp.2064-2077, 2008.

[6] B. Shield, R. Conetta, J. Dockrell, D. Connolly, T. Cox, and C. Mydlarz, "A survey of acoustic conditions and noise levels in secondary school classrooms in England," *J. Acoust. Soc. Am.* vol.137, no.2, pp.177-188, 2015.

[7] G.E. Puglisi, L.C. Cantor Cutiva, L. Pavese, A. Castellana, M. Bona, S. Fasolis, V. lolorenza, A. carullo, A. Burdorf, F. Bronuzzi, and A. Astolfi, "Acoustic comfort in high-school classrooms for students and teachers," *Energy Procedia*, vol.78 no.1, pp. 3096-3101, 2015.

[8] E. Sala, L. Ranrala, "Acoustics and activity noise in school classrooms in Finland," *Appl. Acoust.* vol.114, no.12, pp. 252-259, 2016.

[9] Y. J. Choi, "Evaluation of acoustical conditions for speech communication in active university classrooms," *Appl. Acoust.* vol.159, no.2, pp. 107089, 2020.

[10] Y. J. Choi, "The intelligibility of speech in university classrooms during lectures," *Appl. Acoust.* vol. 162, no.5, pp.107211, 2020.

[11] Y. J. Choi, "Towards better acoustic conditions in school buildings in Korea-a need for Korean standard for classroom acoustics," *J. Acoust. Soc. Kr.* vol. 42, no.2, pp.113-123, 2023.