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Post-Occupancy Evaluation of the Acoustic Performance of an Architecture Faculty Lecture Room Using Objective and Subjective Data

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ABSTRACT
Acoustic comfort is one of the important parameters determining the interior quality of educational buildings by affecting speech intelligibility and students' cognitive performance in learning environments. This study comprehensively examines the acoustic performance of a lecture room used for undergraduate education in the Faculty of Architecture of a university in Türkiye, using objective and subjective data within the framework of the Post-Occupancy Evaluation (POE) approach. In this context, the study measures the reverberation time of the lecture room according to relevant standards and evaluates students' perceptions of acoustic comfort through a questionnaire covering noise and its sources, seating position, speech intelligibility, spatial acoustic quality, and the behavioral effects of acoustic conditions. The findings show that the lecture room does not meet the recommended reverberation time limit and requires improvement, particularly for speech-based educational activities. The results also show that, although the low level of student satisfaction is generally consistent with the physical measurements, the analysis does not reveal a statistically significant relationship between reverberation time and user perception. This finding indicates that acoustic comfort cannot be explained by a single physical parameter. The study concludes that seating position, speaker-student distance, noise, and visual/auditory communication conditions should be evaluated together.
Keywords: acoustic performance, post-occupancy evaluation (POE), educational buildings, reverberation time, user perception.

1. INTRODUCTION
Educational buildings are crucial structures that provide physical environmental conditions directly affecting students' cognitive performance, learning efficiency, and user comfort. Key components of indoor environmental quality in these buildings include thermal comfort, visual comfort, indoor air quality, and acoustic comfort (Bluyssen, 2016; Altomonte et al., 2020). Among these components, acoustic comfort is critical in educational buildings due to its direct impact on speech intelligibility and the learning process (Klatte et al., 2013).

One of the most widely used objective criteria for evaluating acoustic performance in classroom settings is reverberation time (ISO 3382-2, 2008; Bradley, 2011). Reverberation time refers to the time it takes for sound energy to decrease by 60 dB after the sound source stops, and it is one of the fundamental room acoustics parameters affecting speech intelligibility (Long, 2014). If the reverberation time exceeds the recommended limit, consecutive speech sounds may overlap, reducing speech intelligibility, increasing listening effort, and contributing to cognitive load, especially among students (Bradley, 1986; Klatte et al., 2013; Mealings, 2023). Therefore, the acoustic performance of educational buildings is evaluated according to objective criteria defined in international standards (ANSI/ASA

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S12.60-2019; Department for Education, 2015). In this context, ISO 3382-2 (2008) defines methods for measuring reverberation time in ordinary spaces, ANSI/ASA S12.60-2019 specifies the maximum permissible background noise level and recommended reverberation time criteria for educational buildings, and Building Bulletin 93 (BB93) sets out design and performance principles for different educational spaces (Department for Education, 2015). In addition, the DIN 18041:2016-03 standard defines the necessary acoustic conditions and planning criteria for ensuring speech intelligibility. It evaluates spaces such as classrooms, seminar rooms, and lecture halls and recommends determining the reverberation time according to room volume for these spaces. Furthermore, it states that reverberation time values at different frequencies should also be considered (DIN 18041:2016-03).

However, assessments based only on physical acoustic measurements cannot fully explain how users experience the space and perceive the acoustic environment. Educational environments with similar objective acoustic performance values can generate different levels of perceived acoustic comfort depending on factors such as users' individual characteristics, spatial expectations, and the nature of educational activity (ISO 12913-1, 2014; Aletta et al., 2016). The perception of acoustic comfort is influenced by numerous physical, psychological, and contextual variables, including speech intelligibility, sustained attention, the level of noise disturbance, the learning activity being performed, and individual expectations. Therefore, in recent years, it has been suggested that the evaluation of the acoustic performance of educational buildings should include not only objective acoustic measurements but also subjective assessments and survey studies that reveal user experience (Kang et al., 2016; Zhang et al., 2024). Zhang et al. (2024) examined acoustic comfort in educational buildings and highlighted the significant increase in research on this topic in recent years. The study emphasized that various methods have been employed to assess acoustic conditions and that the relationship between acoustic quality and user experience requires more comprehensive investigation.

In this context, the Post-Occupancy Evaluation (POE) approach, which considers physical performance data and user experiences together, stands out as a suitable method for evaluating the acoustic performance of educational buildings. POE is a systematic evaluation approach that assesses the performance of a building during its usage period in line with user requirements and design goals, considering both technical performance and user satisfaction (Watson, 2003; Tookaloo & Smith, 2015). POE studies conducted in educational buildings show that combining user feedback with physical measurements can contribute significantly to understanding the performance of learning environments and informing future design decisions (Whittem et al., 2022; Ezz et al., 2025). In recent years, there has been an increasing interest in research on higher education buildings to evaluate user satisfaction and indoor environmental quality together. However, a significant portion of existing studies focus on the overall building performance or different components of indoor environmental quality in educational buildings. Studies that consider acoustic performance together with students' perceptions of acoustic comfort through on-site reverberation time measurements remain more limited (Manahasa & Özsoy, 2016; Tookaloo & Smith, 2015; Zhang et al., 2024; Ezz et al., 2025).

Architectural education is a unique learning environment requiring high speech intelligibility, as it includes discussions, critique sessions, presentations, and interactive learning processes in addition to traditional lectures. Therefore, it is important to evaluate the acoustic performance of architectural classrooms not only from a technical perspective but also from the perspective of user experience. In this study, the acoustic performance of a lecture room in the Faculty of Architecture was examined using a combination of objective and subjective evaluation methods. First, factors affecting the acoustic environment in the lecture room were investigated through spatial observation, then the reverberation time of the lecture room was measured, and finally, students' perceptions of acoustic comfort were evaluated through a survey. The findings were interpreted together within the framework of the POE approach, revealing the relationship between measured

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acoustic performance and user perception. Thus, this study aims to contribute to user-centered acoustic performance evaluation in higher education buildings. A particular contribution of this study is the integration of acoustic measurements with students' perceptions associated with different seating zones within an architecture education setting. Rather than evaluating the lecture room only as a single acoustic environment, the study examines how acoustic conditions and students' perceptions vary according to their positions within the room. This spatial perspective enables the comparison of objective reverberation characteristics with the perceived acoustic conditions of different seating zones and provides a more detailed understanding of acoustic comfort in architecture education spaces.

2. METHODOLOGY

The research method was designed based on the POE approach (Figure 1). The main purpose of the POE approach is to evaluate the performance of a space not only through its physical and measurable characteristics, but also by considering the relationship between the characteristics of the spatial system, its usage patterns, and user experience. Accordingly, to comprehensively present the acoustic performance of the lecture room, three complementary data sources were used: spatial observation, objective measurement, and subjective user evaluation.

As part of objective evaluations, the reverberation time of the lecture room was measured, and the obtained measurement results were compared with the limit values recommended in Building Bulletin 93, which is used in the evaluation of acoustic performance in educational buildings. However, since measurement results alone are insufficient to explain the actual usage conditions of the space and the acoustic experience of the users, the use of the lecture room, seating arrangement, speaker and student positions, spatial characteristics, and existing conditions that may affect acoustic conditions were also evaluated through spatial observation. Within the scope of the POE approach, students' perceptions of acoustic comfort were collected through surveys to model user evaluations, and the obtained data were evaluated using frequency analysis and Spearman correlation analysis.

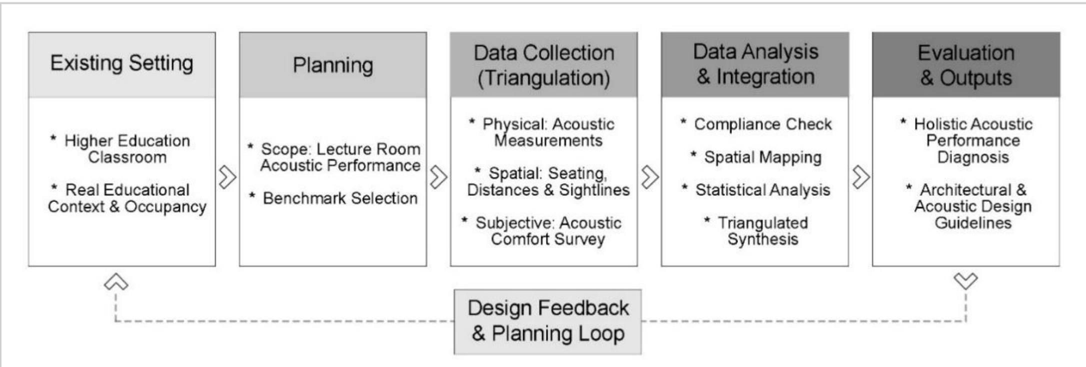

Figure 1. Methodological framework of the POE-based acoustic performance evaluation.

2.1. Study Area

The study was conducted in Lecture Room 2 (LR2), selected from among the undergraduate classrooms within the Faculty of Architecture of a university in Türkiye. Following observations made within the Faculty of Architecture building and preliminary interviews with users, LR2, which was reported to have unfavorable acoustic conditions, was chosen as the study area for detailed investigation. Located on the ground floor of the building, LR2 is an educational space where theoretical lectures are given, as well as discussion, critique, and presentation sessions specific to architectural education are conducted, and where intensive verbal interaction takes place between faculty and students. LR2 has a floor area of approximately 176 m² and a volume of 670 m³. It has dimensions of 9.45 m × 18.65 m and a rectangular plan (Figure 2). The room has a ribbed slab, a height of 3.80

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m from the floor to the underside of the slab, and a capacity of 60 people. It features a traditional seating arrangement consisting of tables and chairs (Figure 3).

The materials used on the interior surfaces of the lecture room directly affect its acoustic performance. The ceiling is left unfinished, with the underside of the structural ribbed slab exposed. This indicates that there is no acoustic-absorbing coating on the ceiling surface, and the surface retains its sound-reflecting properties. The floor is covered with polyvinyl chloride (PVC)-based flooring material. The walls consist of plastered and painted aerated concrete or reinforced concrete surfaces, with wooden cabinets extending along one of the lecture room walls. LR2 has four windows, which are double-glazed and fitted with aluminum frames. Access to the space is provided through a double-leaf wooden door.

The ventilation/HVAC ducts are installed in an exposed, suspended configuration, which introduces irregularities in the surface geometry and may also constitute a potential noise source. The projector is ceiling-mounted. LR2 is surrounded by a corridor, a stepped-seating area, and adjacent classrooms, while an open-plan studio is located on the floor above and the exterior facade faces the garden. This spatial context indicates that the lecture room may potentially be exposed to both internally generated noise from adjacent classrooms, the corridor, and the stepped-seating area, and externally generated noise from the garden and other open areas.

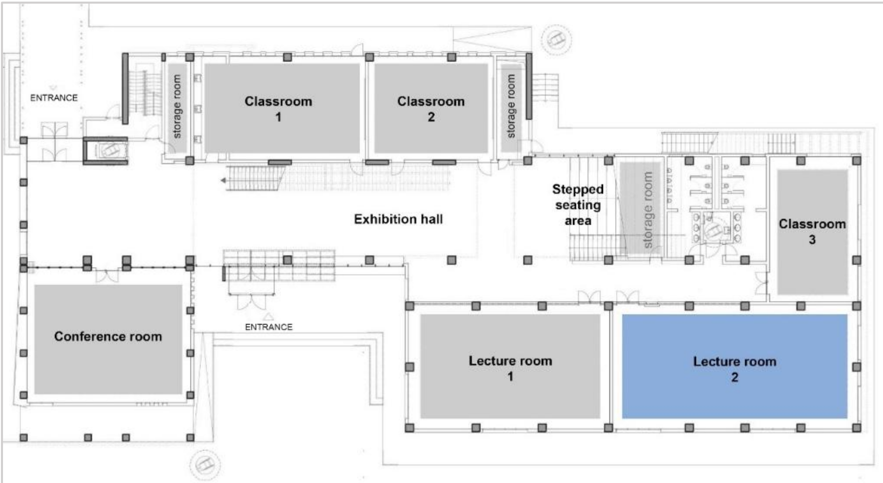

Figure 2. Location of LR2 on the ground-floor plan of the Faculty of Architecture building.

Figure 3. Seating arrangement in LR2.

2.2. Reverberation Time Measurements

As part of the objective data collection component of the study, reverberation time (T30) measurements were carried out to determine the acoustic performance of LR2. Measurements were performed using the equipment specified in Table 1, based on the method defined in the ISO 3382-2:2008 standard. The microphone was calibrated using a calibrator before the measurements were taken.

Table 1. Equipment used for reverberation time measurements.

Equipment	Model	Image
Handheld dual-channel acoustic analyzer	Brüel & Kjær 2270-A-D00	
Amplifier	Brüel & Kjær 2734-A	
Omni-directional loudspeaker	Brüel & Kjær 4292-L	
Calibrator	Brüel & Kjær 4231	

Reverberation time measurements were performed in 1/1 octave bands within the 125–4000 Hz frequency range. In the measurements, the sound source was positioned to represent the instructor's speaking position, while the receiver points were distributed across nine different seating zones within LR2 to represent the students' seating arrangement. During this distribution, care was taken to ensure that the sound source and receiver points were 1.50 m away from the nearest wall surface and other relevant measurement points. The placement of the measurements taken at a total of 1 source and 13 receiver points, and their distribution according to the zones are shown in Figure 4.

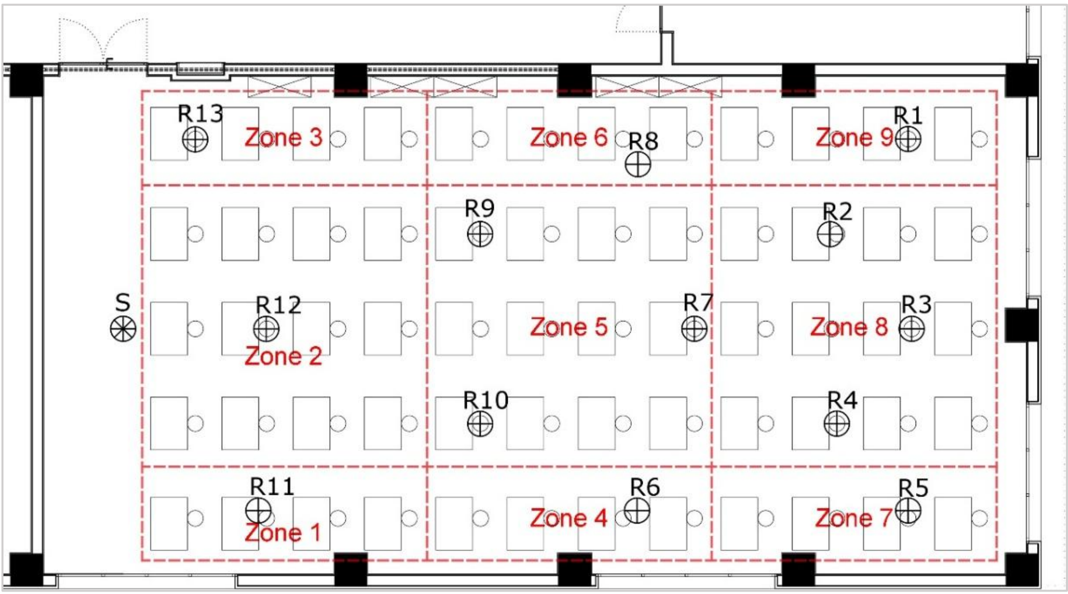

Figure 4. Source (S) and receiver (R) positions for reverberation time measurements and seating zones in LR2.

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The microphone was set at a height of 1.50 metres for the source and 1.20 metres for the receivers. Doors and windows were kept closed during measurements, and care was taken to ensure that there were no external factors that would disrupt the normal operating conditions of the environment. For each measurement point, reverberation time values in the 1/1-octave bands from 125 to 4000 Hz were measured using ODEON 15 Auditorium acoustic analysis software, and the reverberation time of LR2 was evaluated. To compare the measurement results with the reference values specified in Building Bulletin 93 (BB93), the arithmetic mean of the reverberation time values at 500, 1000, and 2000 Hz, representing the speech frequency range, was calculated (T_{mf} / mid-frequency reverberation time), and the evaluations were conducted based on T_{mf}.

For the zone-based analysis, the lecture room was divided into nine seating zones according to the spatial distribution of the acoustic measurement positions shown in Figure 4. For zones containing multiple receiver positions, the T_{mf} value was calculated as the arithmetic mean of the corresponding receiver values; for example, the T_{mf} values of R7, R9, and R10 were averaged for Zone 5, while those of R2, R3, and R4 were averaged for Zone 8. The subjective variable was obtained from the number of students identifying each zone as the acoustically most problematic area. Thus, the analysis comprised nine spatial observations ($n=9$), with one T_{mf} value and one corresponding student-perception frequency for each zone. Spearman's rank correlation was used to examine the monotonic association between the T_{mf} values and students' perceived acoustic problem levels.

2.3. Acoustic Environment and Noise Assessment Survey

The survey form, which constitutes the subjective data collection component of the study, was developed to determine the acoustic comfort level of LR2 within the Faculty of Architecture, based on user perception. The survey was carried out online via the Microsoft Forms platform to a total of 155 students attending the class, all of whom reported no hearing loss or ear-related problems. Students were asked to indicate their seating position in the lecture room on the survey form and to base their evaluations on this position. This approach ensured that the subjective evaluations reflected the students' actual seating positions within LR2.

The survey form consists of two sections. The first section collects information on the demographic and physiological characteristics of the students, such as age and gender. In this section, students were also asked to rank the environmental factors that bother them most in their daily living environments (noise, ambient temperature, light level, air quality, etc.) in order of importance, thus attempting to determine the importance of the acoustic factor among other indoor comfort components. The second section constitutes the main body of the survey and is designed for an in-depth assessment of perceptions related to acoustic comfort. In this context, students were asked questions covering various dimensions, from comparative noise perception and indoor acoustic quality mapping to speech intelligibility and the effects of adverse acoustic conditions.

- Comparative noise perception: Students were asked to identify up to three classrooms in the building that they found to be the noisiest. Thus, the acoustic comfort of the lecture room under study was evaluated in relation to other classrooms in the building, based on user perception.
- Noise source identification: Students were asked to identify the noise sources they perceived in the lecture room, including the ventilation system, projector, corridor noise, neighboring classrooms, conversations between students, and noise from outside the building.
- Spatial data and in-space acoustic comfort mapping: Students' seating positions in the lecture room were recorded, and the room plan was divided into nine zones. Students were asked to mark the zone where they perceived the acoustic conditions to be the most unfavorable, considering their location and previous experiences. The aim was to determine the distribution of acoustic perception within the room and to visually demonstrate the spatial differences in acoustic performance in LR2.

- Communication and perception of intelligibility: Students' subjective evaluations of visual and auditory communication opportunities with the instructor and the intelligibility of the instructor's speech were determined. These evaluations were used to reveal the perceptual dimension of lecture room communication conditions and speech intelligibility on the student experience.
- Behavioral responses and perceived effects: Behavioral responses developed when unable to hear the instructor (moving to the front row, standing up, etc.) and cognitive and physical effects caused by acoustic discomfort (difficulty understanding, distraction, decreased performance, fatigue, headache/tension) were identified.

3. FINDINGS AND DISCUSSION

The results regarding the acoustic performance of LR2 were obtained by evaluating data derived from spatial observations, objective acoustic measurements, and subjective user assessments.

Spatial observations have shown that LR2 has some features that could negatively affect acoustic performance. The long rectangular layout increases the distance to the speaker, especially in the back rows. Sato & Bradley (2008) stated that the effect of delayed sound components is related not only to the reverberation time but also to the room volume and source-receiver distance, and that students getting closer to the speaker can reduce the negative effects of reverberation on speech. The dominance of hard and reflective surfaces on the ceiling, floor, and walls, and the absence of a sound-absorbing coating on the ceiling, create an environment conducive to the persistence of sound energy in the space for a longer period. Supporting this assessment, Peng et al. (2015) demonstrated that applying sound-absorbing material to the classroom ceiling improved reverberation time and other objective acoustic parameters, and enhanced speech intelligibility. LR2 is surrounded by corridors, stepped seating areas, and adjacent classrooms, which may constitute potential noise sources. In addition, the routing of ventilation ducts through partition walls may create duct openings that compromise the continuity of the walls and negatively affect their sound insulation performance. These characteristics represent important spatial and environmental factors that should be considered when evaluating the existing acoustic conditions of the lecture room. In this context, following spatial observations, objective acoustic measurements of the lecture room and findings related to user evaluations were examined.

Data obtained from reverberation time measurements and subjective user evaluations were considered together to assess the acoustic performance of the lecture room within the framework of a post-occupancy evaluation approach. The values obtained from reverberation time measurements were compared with the reference values recommended for educational buildings within the scope of Building Bulletin 93. Survey data were analyzed using descriptive statistics, and frequency distributions were calculated.

The relationship between reverberation time measurements and user perception was investigated by evaluating the results together. In this context, the reverberation time (T30) values measured at 13 receiver points and the arithmetic mean (T_{mf}) of the reverberation time values in the 500, 1000, and 2000 Hz bands are presented in Table 2.

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Table 2. Reverberation time (T30) values (s) measured at 13 receiver positions.

Receiver points	Frequency						T_{mf}
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**500-1000-2000 Hz**
R1	3,40	3,31	**3,29**	**2,83**	**2,21**	1,61	**2,78**
R2	3,37	3,29	**3,16**	**2,85**	**2,33**	1,56	**2,78**
R3	3,22	3,49	**3,27**	**2,82**	**2,35**	1,58	**2,81**
R4	3,79	3,17	**3,07**	**2,83**	**2,24**	1,54	**2,71**
R5	3,48	3,53	**3,41**	**2,69**	**2,25**	1,59	**2,78**
R6	3,85	3,42	**3,17**	**2,69**	**2,30**	1,53	**2,72**
R7	3,64	3,45	**3,30**	**2,70**	**2,27**	1,52	**2,76**
R8	3,24	3,41	**3,07**	**2,88**	**2,22**	1,53	**2,72**
R9	3,90	3,27	**3,02**	**2,70**	**2,25**	1,54	**2,66**
R10	3,52	3,46	**2,98**	**2,74**	**2,25**	1,55	**2,66**
R11	3,21	3,23	**3,29**	**2,78**	**2,19**	1,53	**2,75**
R12	3,31	3,43	**3,00**	**2,90**	**2,25**	1,56	**2,72**
R13	3,65	3,29	**3,07**	**2,79**	**2,25**	1,52	**2,70**

According to the BB93 standard, the recommended mid-frequency reverberation time (T_{mf}) for lecture rooms should be less than 1.0 seconds. In line with this, measurements conducted in LR2 revealed that the reverberation time values obtained at all 13 receiver points were significantly above the determined limit. To evaluate these objective measurement results together with users' perceptions of the acoustic environment, survey data from lecture room users was also examined.

The participant profile and demographic characteristics of the survey, which was conducted to evaluate users' perceptions of acoustic comfort, were examined. A total of 155 students participated in the survey. The students' ages ranged from 18 to 29, with 76.8% being female and 50.3% being between 21 and 23 years old.

When environmental comfort components were evaluated within the scope of the study, it was observed that noise was a more significant source of discomfort for students compared to other environmental factors. Noise was ranked first as the most disturbing environmental factor by 32.3% of the students, while air quality came in second with 28.4%. Ambient temperature was ranked third with 11.6%, and light level was ranked fourth with 11.6%. The prominence of noise aligns with the study by Ricciardi and Buratti (2018), conducted in university classrooms, which revealed that acoustic disturbance is a significant environmental comfort issue.

When the perceived noise sources in LR2 were examined (Figure 5), it was observed that the most frequently reported sources were conversations between students (71.6%) and noise from the corridor/stepped seating area (52.3%). Noise from neighboring classrooms was reported at 15.5%, noise from the upper floor at 12.9%, and noise from outside the building at 9%. Noise from furniture, desks, chairs, and student movement, as well as projector noise, was reported separately at 2.6%, while ventilation system noise was reported at 1.9%. 8.4% of students did not specify any source of noise. The findings indicate that the noise perceived in LR2 is predominantly student-generated sounds, as well as noise from nearby spaces outside the lecture room, such as the corridor/stepped seating area and adjacent classrooms.

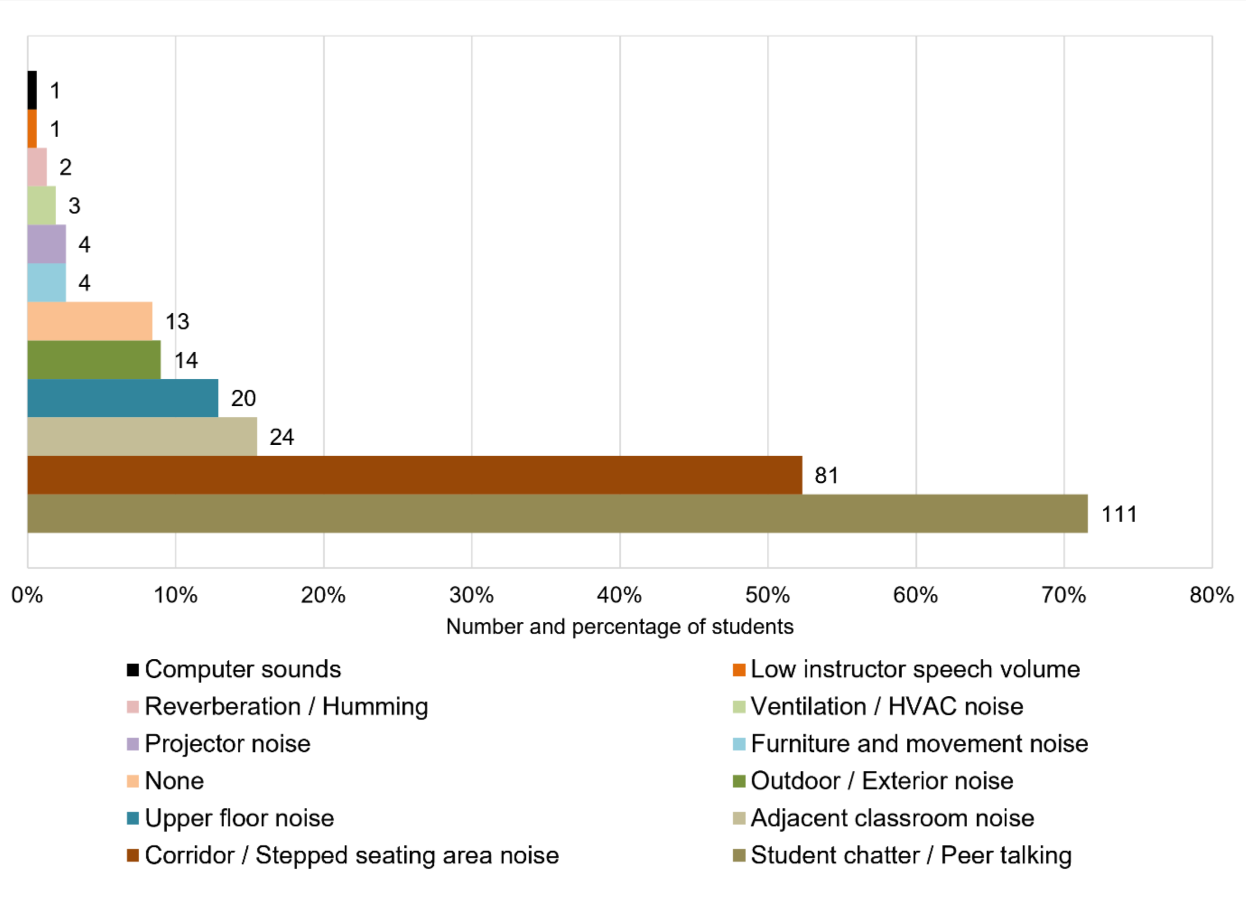

Figure 5. Noise sources perceived by students in LR2.

Students' subjective assessments of their communication with the instructor and their level of understanding of the instructor's speech are presented in Figure 6.a and Figure 6.b, respectively. In evaluations regarding communication with the instructor, 71.0% of students stated that they could see and hear the instructor. However, 21.3% stated that they could see the instructor but could not hear them, 6.5% stated that they could not see the instructor but could hear them, and 1.3% stated that they could neither see nor hear the instructor. Accordingly, it appears that 29.0% of the students experienced at least one problem in terms of visual and/or auditory communication with the instructor (Figure 6a). In evaluations regarding the students' level of understanding of the instructor's speech, 50.3% stated that the speech was easily understood, while 19.4% indicated that it was only slightly understood. In contrast, 25.2% of students stated that the speech was audible but difficult to understand, 4.5% stated that it was barely audible but not understandable, and 0.6% stated that the speech was not audible. Thus, while 69.7% of students found the instructor's speech easily or mildly understandable, 30.3% reported varying degrees of hearing and/or comprehension difficulties (Figure 6b).

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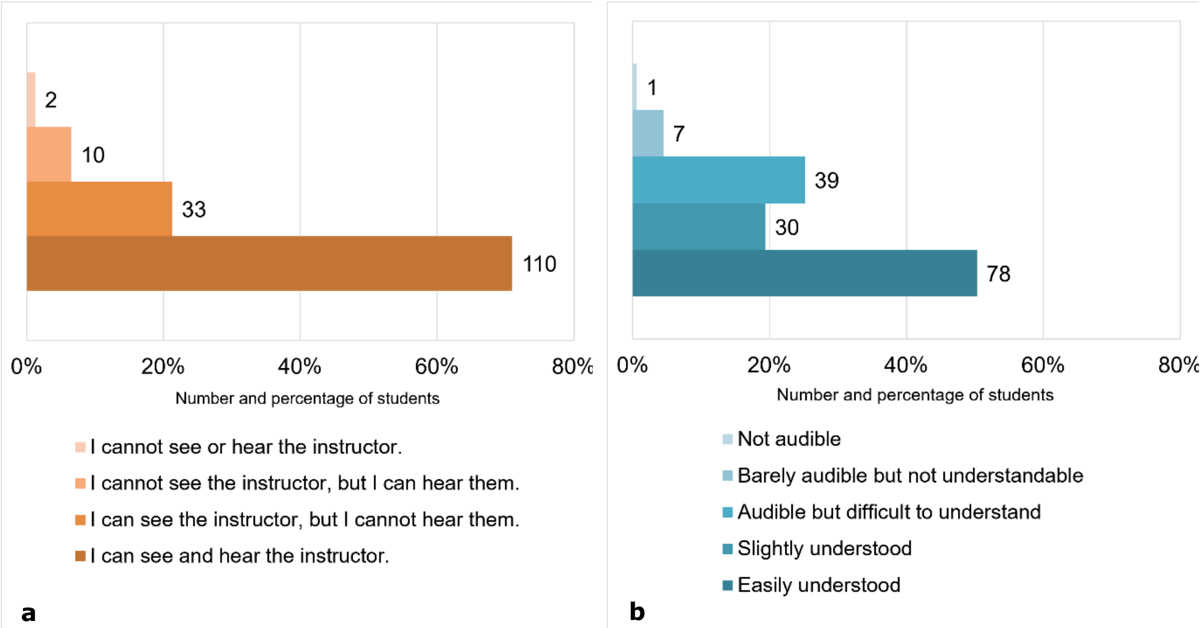

Figure 6. a: Students' ability to communicate with the instructor; b: students' subjective assessments of their ability to understand the instructor's speech.

When the relationship between these two assessments -communication with the instructor and speech intelligibility- was examined, a positive, moderate-to-strong, and statistically significant correlation was found between the variables (Spearman's $\rho = 0.617$; $p < 0.001$). Students who rate their communication with the instructor more positively tend to report that they understand the instructor's words at a higher level. This finding indicates a significant correlation between students' assessments of visual and auditory communication with the instructor and their subjective evaluations of speech intelligibility. The high percentage of students who stated they could see and hear the instructor, and the significant correlation between this communication assessment and speech intelligibility, suggests that the conditions of communication with the instructor should be evaluated in conjunction with students' perceptions of speech intelligibility.

In evaluations of zones where students perceived the worst acoustic conditions based on their previous experiences, responses were concentrated particularly in Zones 7, 8, and 9. 40.0% (n=62) of the students considered zone 9, 27.7% (n=43) zone 7, and 23.9% (n=37) zone 8 to be the most acoustically problematic zone. Zone 5 was mentioned by 3.2% (n=5), zones 2 and 3 by 1.9% each (n=3), and zone 6 by 1.3% (n=2), while zones 1 and 4 were not chosen by any student (n=0). Thus, 91.6% (n=142) of the students considered zones 7, 8, or 9 to be the most acoustically problematic zones in LR2. The measured T_{mf} values (Figure 7a) and the spatial distribution of the zones identified by students as acoustically most problematic (Figure 7b) were evaluated together to compare objective acoustic measurements with subjective spatial perceptions.

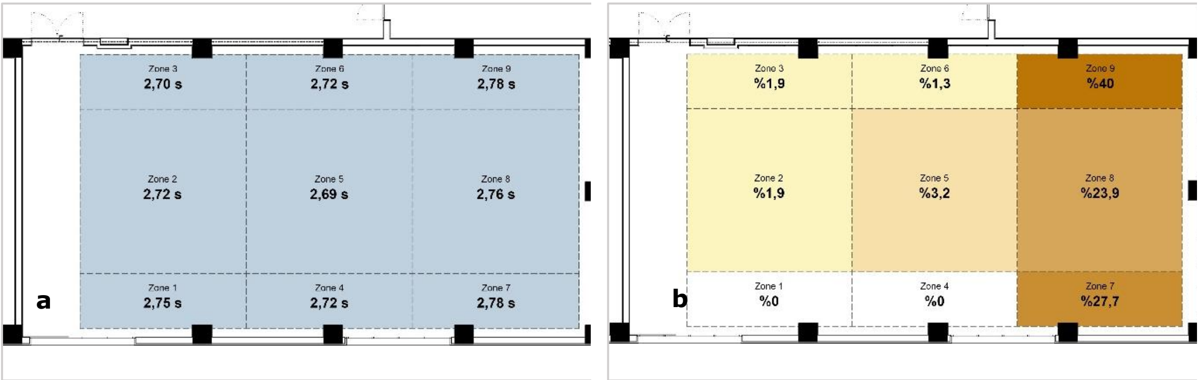

Figure 7. a: Variation in T_{mf} values; b: Variation in the level of acoustic problems perceived by students across different zones.

When the relationship between the zones that students perceived as the most acoustically problematic and the objective T_{mf} measurements were examined, a positive but statistically non-significant correlation was found between zone-based student perception and T_{mf} values (Spearman's $\rho=0.489$; $p=0.181$; $n=9$). However, a notable spatial correspondence can be observed when comparing the spatial distributions of the two assessments. A large majority of the students (91.6%, n=142) indicated one of Zones 7, 8, or 9 as the area with the worst acoustic conditions. In the T_{mf} measurements, these zones also exhibited relatively high values compared with the other parts of the lecture room. However, the relatively small differences in T_{mf} values between the zones indicate that the differences in students' zone-based acoustic assessments cannot be explained only by T_{mf}.

This spatial pattern is also observed in students' evaluations of their visual and auditory communication with the instructor. While 81.4% of students in zones 1–6 of the lecture room stated that they could both see and hear the instructor, this rate dropped to 50.9% in zones 7–9. Conversely, the percentage of students who stated that they could see the instructor but could not hear them increased from 15.7% in zones 1–6 to 32.1% in zones 7–9. It is also noteworthy that all students who stated that they could neither see nor hear the instructor were in zones 7–9. These findings indicate that students in the back zones of the lecture room may experience more difficulties with auditory communication with the instructor.

A positive and statistically significant correlation was found between communication assessment with the instructor and speech intelligibility (Spearman's $\rho=0.617$; $p<0.001$). This result indicates that students' subjective assessments of speech intelligibility and their evaluations of visual and auditory communication conditions with the instructor change together. Therefore, student position within the lecture room, distance from the instructor, and visual communication conditions can be considered spatial factors that should be considered in students' evaluations of speech intelligibility.

In addition, perceived noise sources in the lecture room should also be considered in explaining zone-based assessments. 52.3% (n=81) of students indicated noise from the corridor/stepped seating area, and 15.5% (n=24) indicated noise from neighboring classrooms as a noise source. Zones 7, 8, and 9 share a common dividing wall with adjacent classrooms, and ventilation and lighting systems pass through this wall. These architectural features may represent potential pathways for sound transmission from adjacent spaces; however, their specific contribution to the perceived acoustic conditions was not directly measured in the present study. Therefore, acoustic problems in these zones should be considered not only in terms of reflection characteristics but also in conjunction with surrounding noise sources and spatial location. However, zone 3 presents a different pattern. Although the T_{mf} value in this zone does not differ significantly from other zones of the LR2, it was indicated as acoustically problematic in the students' zone-based assessments. The proximity of this zone to the door and corridor connection can be

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considered a possible explanation for exposure to corridor-related noise. This supports the idea that students' perception of acoustic comfort cannot be explained only by reverberation time; noise sources, the student's position within the space, and the conditions of visual/auditory communication with the instructor must also be considered together.

Figure 8 presents students' assessments of the effects of acoustic conditions. When examining the effects that students reported experiencing under unsuitable acoustic conditions, the most frequently reported effect was impaired concentration (83.2%). Difficulty understanding what was being said (69.7%) and headaches, irritability, anxiety, and tension (55.5%) were also among the most common effects. 43.2% of students reported getting tired easily, 29.0% had difficulty taking notes, 20.0% reported receiving a low grade on an exam, and 19.4% experienced a decrease in performance. Only one student (0.6%) stated that acoustic conditions had no negative effects.

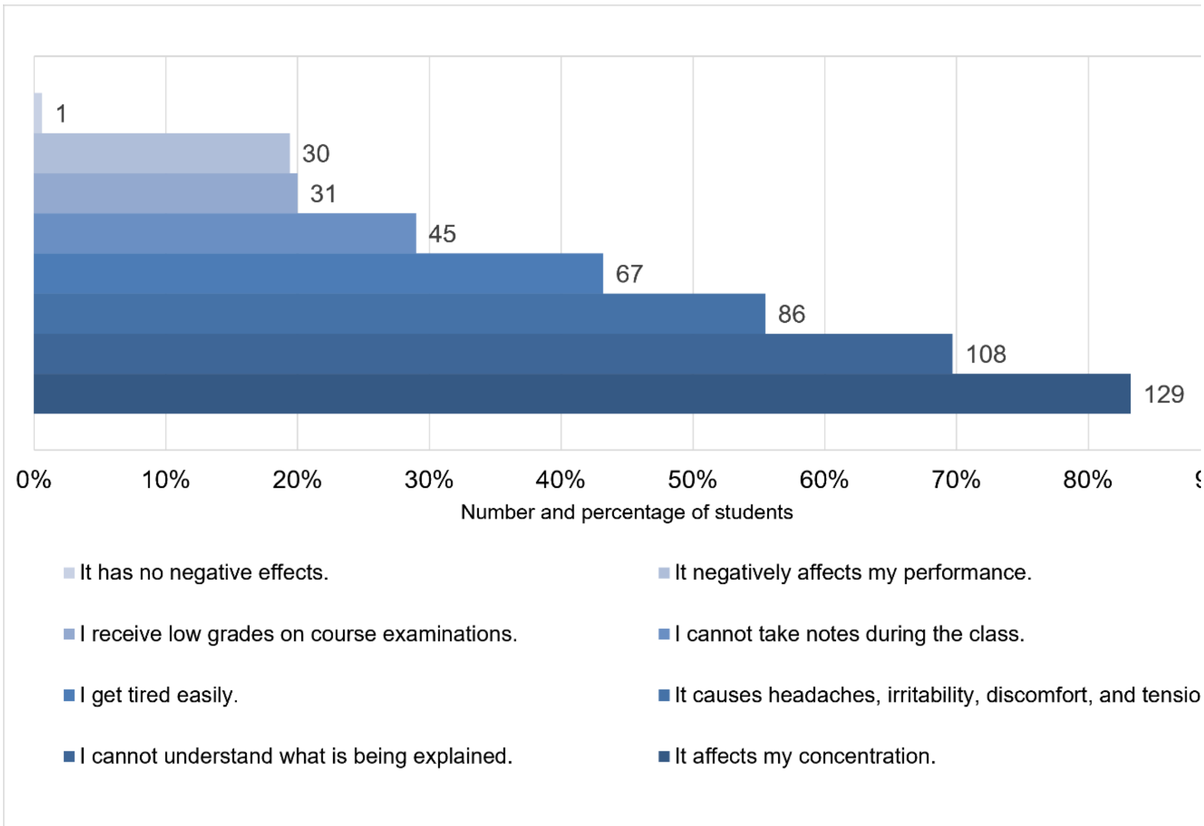

Figure 8. Effects of lecture room acoustic conditions on students.

The high rate of difficulty understanding what is being said, when considered together with the high rate of difficulty taking lecture notes, suggests that acoustic conditions may be related to students' learning experience through the perception and simultaneous processing of verbal information. These findings are consistent with the literature showing that inadequate classroom acoustics can negatively affect students' listening, learning, and well-being. It has been noted that high noise levels and long reverberation times can negatively impact speech perception, listening comprehension, and cognitive performance (Klatte et al., 2013; Mealings, 2023). Mealings (2023), in a study involving university students, reported that adverse acoustic conditions, such as high noise levels, low signal-to-noise ratios, and long reverberation times, generally had negative effects on listening, learning, and well-being. Students appeared to perceive problems related to acoustic conditions not only as auditory issues but also as comfort-related problems associated with concentration, comprehension, and psychophysiological well-being. This finding is consistent with the results reported by Ezz et al. (2025), Benjamin and Alibaba (2019), and Glean et al. (2022), which demonstrate that acoustic conditions affect not only auditory comfort but also users' attention, communication, and learning experiences.

When examining the strategies students use in response to difficulties hearing the instructor, 85.1% of students stated that they moved to the front rows to hear better. 38.3% of students requested the instructor to raise their volume, 12.8% took no action, 8.5% tried to hear by standing up and increasing visual contact, and 2.1% recorded the speech from a location close to the instructor (Figure 9). The high tendency of students to sit in the front rows indicates that they prefer to position themselves closer to the speaker in the face of difficulties in communication and speech intelligibility.

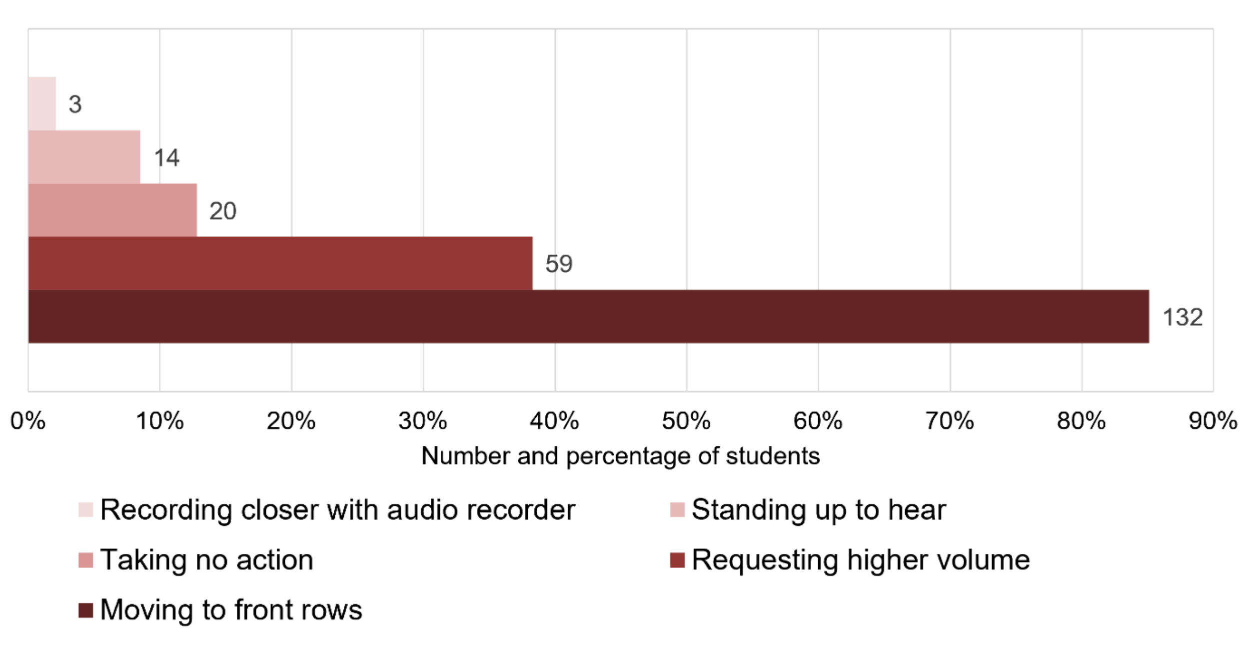

Figure 9. Actions taken by students when the instructor is not clearly audible.

Overall, the findings indicate that students' acoustic comfort and communication experiences cannot be explained only by the reverberation time of the lecture room. While a related pattern exists between acoustic conditions and students' spatial location, opportunities for visual and auditory communication with the instructor, and speech intelligibility, the lack of a statistically significant relationship between reverberation time and student perceptions reveals that acoustic experience has a multidimensional structure. It is understood that spatial and environmental variables such as students' distance from the speaker, line of sight, seating position, and ambient noise have an impact on the perceived quality of communication. As the study was conducted in a single lecture room, the findings should be interpreted within the context of the investigated setting. Future studies may further strengthen the assessment by considering additional acoustic parameters, such as background noise, speech intelligibility, and sound insulation, together with reverberation time across different classroom configurations.

4. CONCLUSIONS

This study evaluated the acoustic performance of a higher education lecture room within a Post-Occupancy Evaluation (POE) framework by integrating spatial observations, objective acoustic measurements, and user evaluations through a holistic approach. The findings revealed that the lecture room's existing acoustic conditions did not fully meet the recommended performance criteria, and that this was also related to how students used and perceived the space. Reverberation time measurements showed that the lecture room needed acoustic improvement, especially for speech-based learning activities. The fact that student evaluations also indicate a low level of satisfaction regarding the acoustic environment suggests a general agreement between physical measurements and user

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experience. However, the lack of a statistically significant relationship between reverberation time and student perception indicates that acoustic comfort cannot be explained by a single physical parameter. Variables such as noise level, instructor–student distance, seating position, and students' visual access to the instructor need to be considered together. The prominence of spatial location in the findings indicates that lecture room design should particularly consider the back rows. The decrease in direct sound level and weakening of visual/auditory communication conditions as students move away from the instructor can negatively affect the learning experience of students in the back rows. Furthermore, background noise, reverberation time, and spatial geometry need to be considered together.

The recommendations directly supported by the present measurements and student evaluations concern seating position, instructor–student distance, and visual and auditory communication. When evaluating the acoustic performance of a lecture room, it is important to consider not only the acoustics of the space itself but also the transmission of noise from external and adjacent spaces through building elements. The presence of corridors, open studios, and adjacent classrooms around the lecture room suggests that noise from adjacent spaces may affect the auditory conditions within the lecture room. Furthermore, routing ventilation ducts through partition walls can create utility passages that disrupt the continuity of the wall and weaken sound insulation performance. Therefore, all service penetrations through building elements should be acoustically evaluated during the design and construction phases. Where necessary, acoustic continuity should be ensured through appropriate insulation details and acoustic sealing solutions. Considering that doors are also a critical component in sound transmission between the lecture room and corridors and other common areas, it is recommended to use doors with adequate sound insulation performance. Similarly, implementing acoustic measures and appropriate detail solutions to reduce sound transmission through ducts in ventilation systems will contribute to ensuring the continuity of sound insulation between the lecture room and surrounding spaces.

Other design recommendations concerning sound insulation, acoustic detailing, and classroom typology are informed by spatial observations and relevant literature. Rather than accommodating theoretical and practical educational activities within the same spatial configuration, it is recommended that different classroom typologies be developed according to the communication requirements of each educational format, particularly in schools of architecture. While practical courses require a more flexible spatial organization to support students' work, production, and group interaction, visual and auditory communication between the instructor and students constitutes the primary mode of communication in theoretical courses. Therefore, in theoretical classrooms, spatial dimensions, instructor–student distance, seating arrangement, sightlines, and the position of the instructor should be considered as fundamental components of the design. Particularly in large and deep-plan classrooms, it is important to establish a seating arrangement that allows all students to see the instructor and receive direct sound at an adequate level, rather than focusing on maximizing capacity. Where necessary, spatial solutions such as a sloped floor or a raised instructor platform can be employed to improve sightlines and direct sound conditions for students in the rear rows.

In conclusion, acoustic performance in the design of higher education classrooms should not be limited only to compliance with reverberation time standards. Room acoustics, sound insulation, spatial geometry, user positions, instructor–student distance, sightlines, noise level, and speech intelligibility should be considered as interrelated design variables. Controlling noise that may originate from corridors, open studios, and adjacent classrooms, and ensuring sound insulation continuity at utility passages, doors, and other connection points in building elements, should be considered from the early stages of design. This approach will allow for the differentiation of classrooms, especially in architecture faculties where different teaching methods are conducted together, not only in terms of capacity and function, but also in terms of the visual and auditory communication conditions required for educational effectiveness. Future studies comparing different classroom typologies and examining the relationships among instructor–student distance, spatial geometry, room acoustic metrics, and user perception can contribute to the development of more comprehensive acoustic and spatial design criteria for higher education classrooms.

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Ethics Approval and Consent to Participate
The study was approved (E-43633178-199-157156; July 2, 2024) after ethical review by the Human Research Ethics Committee of Gebze Technical University. Informed consent was obtained from all participants involved in the study. Participation was voluntary and anonymous.

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