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Exploring Adaptive Acoustics for Educational Spaces

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Abstract

Acoustics play a major role in educational buildings as, these have high density, occupying classrooms, lecture halls, conference rooms, auditoriums, and so on, engaged by students for several activities. Due to their multi-functional nature, architectural studios in particular require larger spaces, and these often accommodate furnishings such as drafting boards/tables, screens, and podiums. The considerable volume of these studios can lead to compromised acoustical comfort, which may result in issues like echoes and background noise. Planning and executing these spaces can be challenging, and there is always room for acoustical personalization to enhance the user's experience. This article presents the acoustic personalization of educational spaces aiming to explore the spatial influence on acoustic and identifying methods that would alter acoustics to user preference and needs. The acoustic personalization of existing building can be done through adaptive technologies and relevant materials. The aim is to understand the potential of adaptive acoustics in educational environments and their impact on students' psychological well-being and learning abilities. The data collection method for this research paper involves the case study of architectural department, at DIT University, accompanied by structured surveys with students of different years. The acoustically relevant data such as psychological states before and after entering the space, the impact of background noise, opinions on potential improvement like sound-absorbing material, and overall acoustical comfort is gathered for examining the effects of noise on concentration and learning. This analysis helps prepare a set of guidelines that should cater to common acoustical problems and recommendations for the process of acoustic personalization in educational space, such as designated quiet zones.

Keywords: Personalized soundscape, adaptive acoustics, educational spaces, acoustical technologies, educational buildings

INTRODUCTION

Learning spaces for various educational building of different courses uses somewhat similar lecture halls of similar area, but in case of architectural field the space necessary is larger. The volume of the studios is meant to accommodate several furniture like big drafting table for each student, boards, and screens to conduct lectures, and sometimes podiums and stages. Unlike other spaces these studios are meant to be used for several activities such as drafting, model making, conducting lectures, discussions and many other activities that require comparatively bigger space. Just because of the larger volume of these spaces, the acoustical comfort is compromised, creating several acoustical issues. These issues may create psychological hinderance for the students, affecting their learning ability [1, 2].

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This research paper explores acoustical personalization of educational spaces, role the size of space plays in soundscape, and finding ways to manipulate sound according to user needs. Studying the technologies and elements that can be used for the implementation of this personalization and identify various guidelines that could be implemented for the betterment of existing spaces. The aim is to understand the scope of technologies

and materials in adaptive acoustics and personalization of educational spaces. The main objective is to understand personalized soundscape for educational spaces and the psychological behavior of students with respect to the acoustical comfort. This research is limited exclusively for the architectural studios and lecture halls. Exploring the psychological needs of students.

LITERATURE REVIEW

To explore and understand the acoustical comfort required in educational space, following sources were studied:

- *Achieving acoustic comfort in the architectural design of a lecture hall*: The study focuses on improving acoustical value of lecture halls and classrooms to enhance the learning experience. Exploring the background noise sources, inside and outside the space, and analyzing the current provisions for sound insulation. This research will then help propose design improvements [1].
- *Acoustical quality assessment of lecture halls at Lund University*: This research deals with assessing the acoustical performance of lecture halls at Lund University. It is possible to control the room acoustics through sound absorption and sound masking. This study focuses on evaluating spaces within the university which are built recently as well as many years ago based on their acoustical performance and identify areas for improvement [2].
- *Visual and acoustic adaptability in architecture: effects of level change in users' sensation*: This study explores the relation between the physical and psychological aspect and the acoustical and visual values. Research performed has shown how comfort depends on the surrounding environment. The aim is to find how these factors affect visual and acoustical comfort. By observing the behavior of the individual as they move through various transitional spaces with controlled visual and acoustical condition [3].
- *The birth of intelligent passive room acoustic technology: a qualitative review*: This article explores a concept called IPRAT, referring to Intelligent Passive Room Acoustic Technology. The aim is to improve the acoustical comfort of a space or building automation of adjustment in sound reverberation time (RT). The basics of IPRAT revolves around breaking the traditional building design which uses a single RT, however IPRAT uses to Existing Technologies that are ASC (acoustic scene classification) and PVAT (Passive Variable Acoustic Technology) [4].
- *Development of an acoustically adaptive modular system for near real-time clarity-enhancement*: This research deals with an adaptive computerized system to improve speech clarity in a classroom. The system works in modules which can change their formation to serve the of sound purpose deflection, reflection, or absorption. This system aims to adjust the indoor sound quality and promote better quality acoustics [5].
- *A highly adaptive acoustic echo cancellation*: Teleconferencing requires systems to reduce echoes to enhance a better quality of acoustics. Echo cancellation is a critical task requiring a specific and complex environment working in real-time. This research proposes an adaptive echo-cancellation solution, which is tested and highly efficient for multi-party conferencing [6].
- *Adaptive acoustic origami*: This thesis revolves around examining adjustable origami structures according to the acoustical needs of existing buildings. The aim was to develop a prototype for a room by adjusting and reverberating the time; that is, "how long sound echoes" [7].
- *Architectural acoustics*: The book helps understand the fundamentals of acoustics related to architecture. Outlining the basic applications and conditions required for different buildings [8].
- *Textiles in architectural acoustic conditioning: a review:* This review explores the scope of textile use in acoustical field. Listing out the possible sound-absorbing mechanism of textile and customize their design composition to match the sound space [9].
- *The effect of white noise on psychological stress while performing cognitive tasks and its correlation to performance:* The research focuses on the potential of white noise as to reduce the stress and increase the cognitive performance of the students. By means of exposing the students to three different auditory conditions, they tested their hypothesis [10].

- *The impact of classroom acoustics on scholastic achievement:* This study underlines the importance of acoustics in classroom for efficient learning. It investigates the factors, such as noise and reverberation, that interfere with the learning process. Also highlighting the need for proper investments to be made in acoustically sound classrooms [11].

The concept of these research papers and sources revolves around various aspects of improving acoustical and visual comfort of a space. Some of these studies explore the connection between physical and psychological aspects and how it affects the overall comfort of the environment [3]. Few focuses on improving the existing built environment and identifying irregularities which can affect the comfort of an individual [4]. Few studies examine new technologies or concepts regarding this field which delves deeper into the scientific aspects of sound such as reverberation time, deflection, reflection, absorption, and so forth [5]. Many of these research papers address issues regarding the overall built environment and background noises which can affect the overall acoustic performance of a space. There is also research which exclusively investigates the capability of adjustable origami structures that could be used in existing buildings to address acoustic needs [7].

RESEARCH METHODOLOGY

The research design of this article depicts case study analysis followed by scheduled survey on acoustic related subjects. As the research revolves around educational spaces, a systematic sampling technique was used to identify participant for the surveys, that involved students of different years who are directly or indirectly connected to the spaces. This helped in gathering data regarding student perspective and behavior which sets up the base of this article.

To fulfil the objectives of this research paper the studios of architectural department building at DIT University is taken as a case (Figure 1). The selected site at DIT University has a department building solely dedicated for architecture and planning with studios, lecture halls, computer lab, library, seminar halls, staff rooms, teachers' cabin, pantry, and toilets. The studios are equipped with furniture required for the course (Figure 2).

The focus of this study regarding the acoustical improvement targets the large architectural studios. These spaces occupy heavy furniture like drafting tables and stools, and experience constant background noise from fans, furniture movement, and student conversations. This considerable volume of the room creates echoes, especially when walls lack sound-absorbing materials. Also, the vast space

Figure 1. Site location: DIT University, Dehradun.

Figure 2. Vastu, school of architecture and planning.

makes it difficult for students further back to hear instructors clearly, leading to frequent requests for repetition. The collaborative nature of architectural work, require frequent discussions between students and instructors, further aggravates the issue as sound reflects repeatedly, causing an overall increase in noise level. In addition, external sounds add to the internal noises making the learning more difficult.

The survey was structured around the student psychology before and after entering the space, furniture and materials used, audio visual equipment, and overall acoustical comfort of classrooms. The survey inquired about the overall acoustical satisfaction experienced by the users and intensity of background noise level and the difficulty in using audiovisual equipment in the classroom due to the noise. The times when the students found it difficult to hear and understand the instructor and had to ask them to repeat the instructions. The impact of noise level on the concentration of students during lectures and their ability to learn and memorize the material studied. The types of acoustical problems the students faced such echo or reverberation, excessive background noise from outside the classroom (e.g., traffic, hallway noise), noise from within the classroom (e.g., projector hum, student movement), difficulty understanding speech at a distance from the instructor. The state of mind of student as they enter the room and adjusting to the transition between outdoor and indoor sound level and its effect on the student's ability to learn during lectures and discussions. The difficulty in mentally shifting gears between studio work and lecture/discussion mode in that multifunctional space. Asking about the user opinion on adding sound-absorbing materials and adding designated quiet zones.

RESULTS

The sample of participants consisted of students aged between 20 and 23 years, with the gender composition of 45% male and 55% female. The year distribution was 15% in the 1st year, 25% in the 2nd year, 20 % in the 3rd year, and 40% in the 4th year. From the surveys analysis it is interpretated that:

- A total of 90% of students were not satisfied by the overall acoustical comfort of their classrooms as observed in Figure 3.
- Students described the background noise level in the classroom to be quite high, which also created difficulty using audio visual equipment during the lecture or presentation (Figures 4 and 5).
- Students found it difficult to understand/hear the instructor and often asked the instructor to repeat themselves as the lecture was taken (Figures 6 and 7).

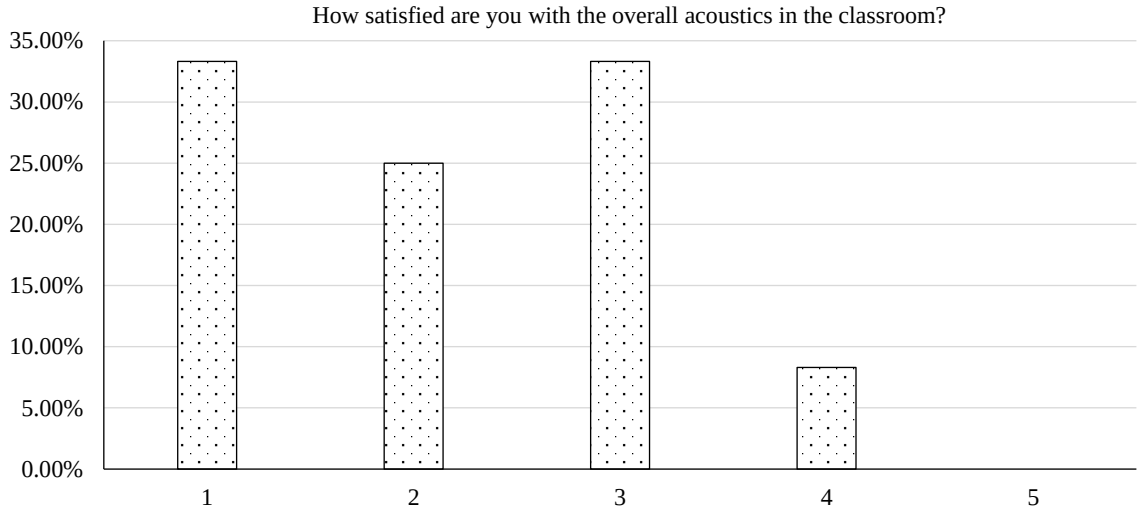

Figure 3. Acoustical satisfaction of students.

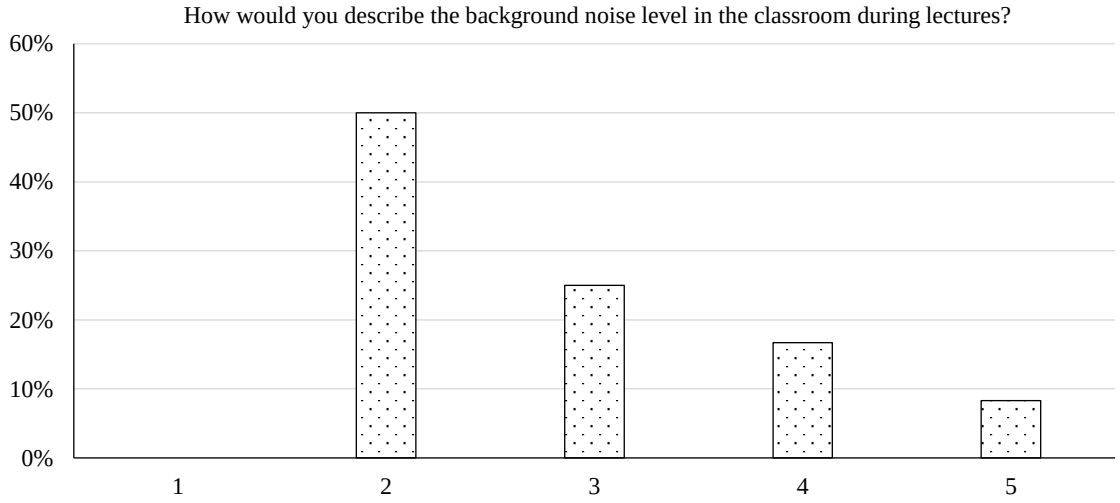

Figure 4. Background noise level.

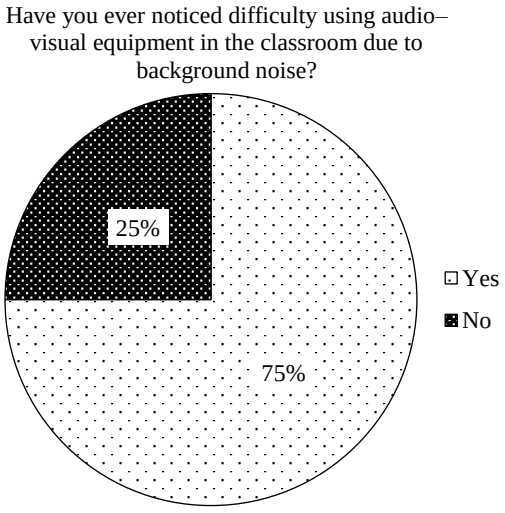

Figure 5. Difficulty in using audio–visual equipment due to background noise.

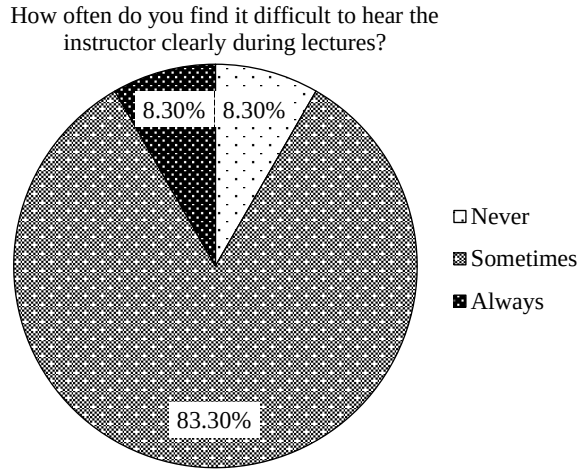

Figure 6. Difficulty in hearing the instructor.

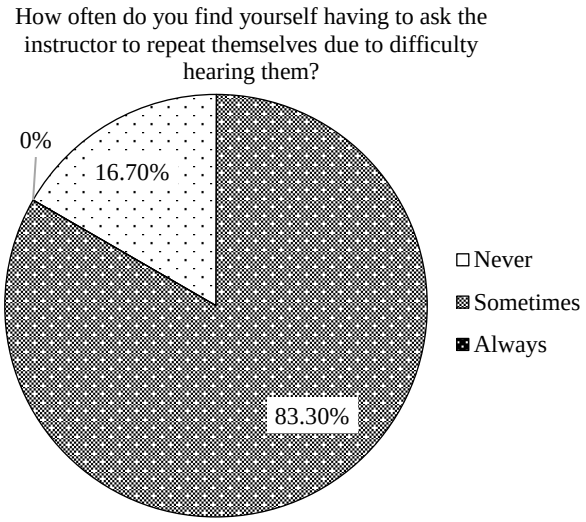

Figure 7. Need to ask the instructor to repeat themselves.

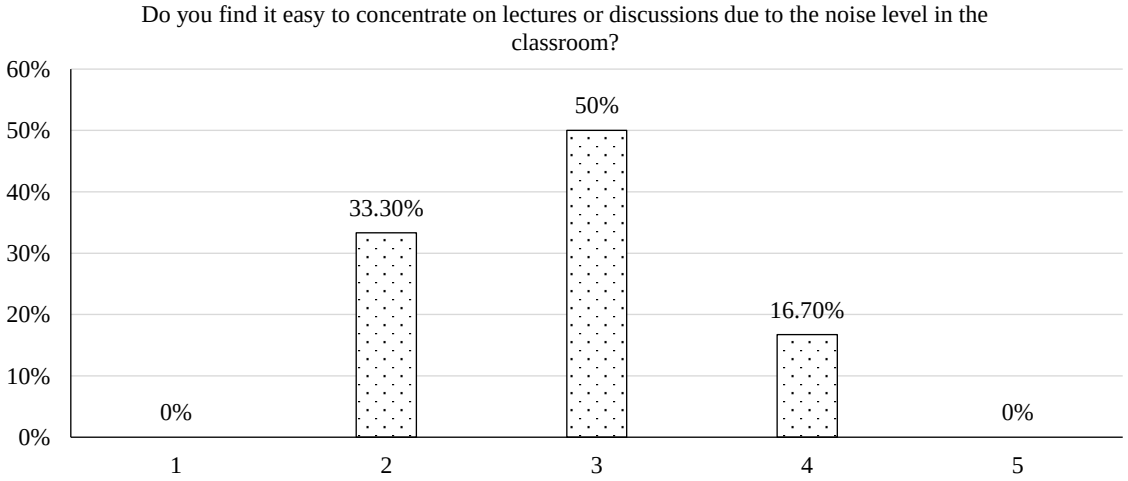

Figure 8. Ease of concentrate on lectures and discussions due to the noise level.

- Students moderately described that their concentration on lectures were hindered due to the noise level in classroom (Figure 8).

- From the options provided in (Figure 9), the survey revealed that the emotional state as they entered the room was between neutral and somewhat anxious, which in addition to the acoustical problem in classroom may affect the ability to learn the material.
- From the Figures 10 and 11, it was observed that the students described the transition in noise level to be moderately impactful on their ability to concentrate.
- As architectural studios are made for both lectures (ideally quieter) and studio work (potentially noisy), hence the back-to-back psychological shift between these activities becomes difficult, as students described (Figure 12).
- Majority of the surveyed students were in favor of adding sound-absorbing materials and all of them wanted to get a designated quiet zone for focused studying (Figures 13 and 14).

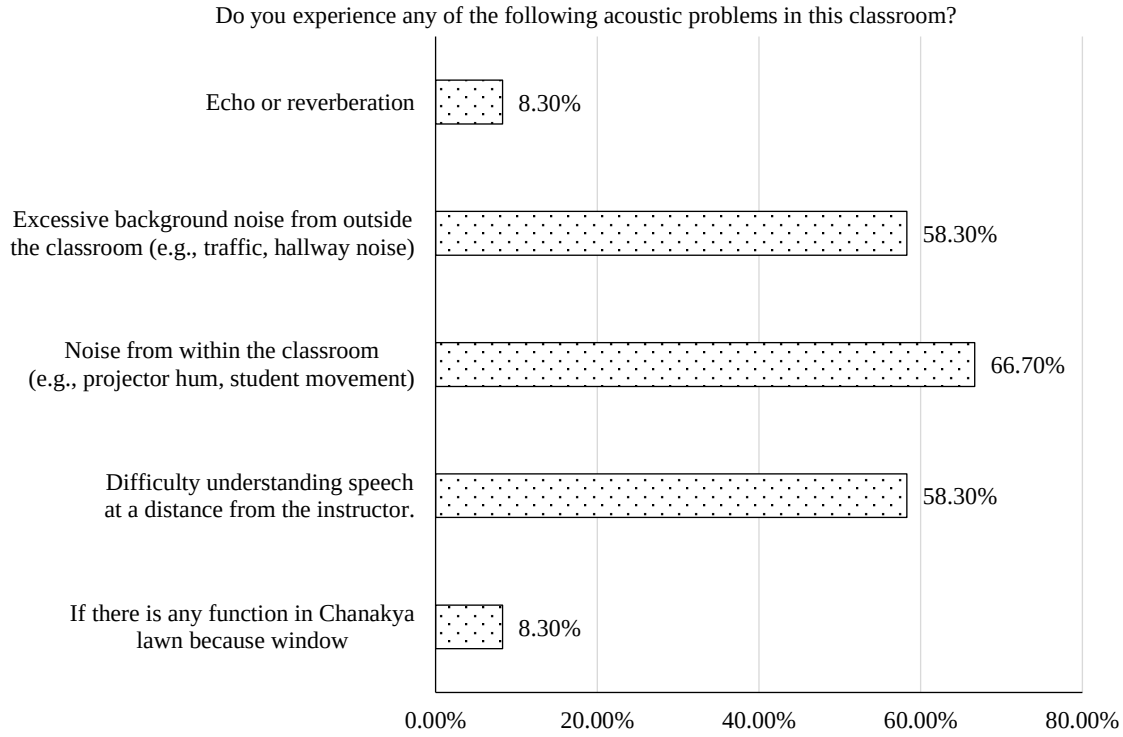

Figure 9. Issues faced by students in classroom.

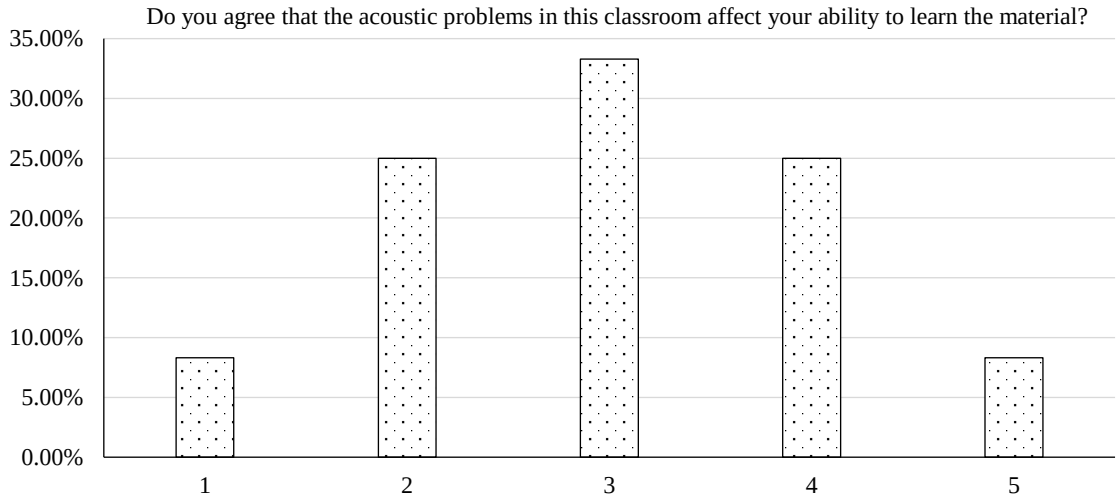

Figure 10. Acoustical issues affecting the student's ability to learn.

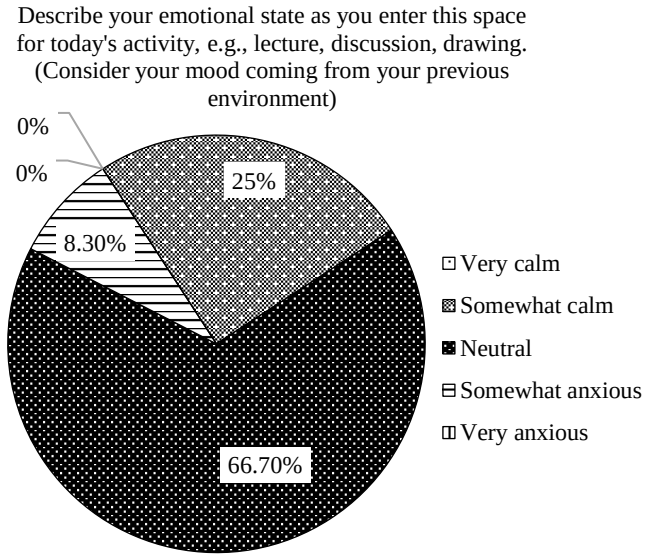

Figure 11. Psychological state of students as they enter the space.

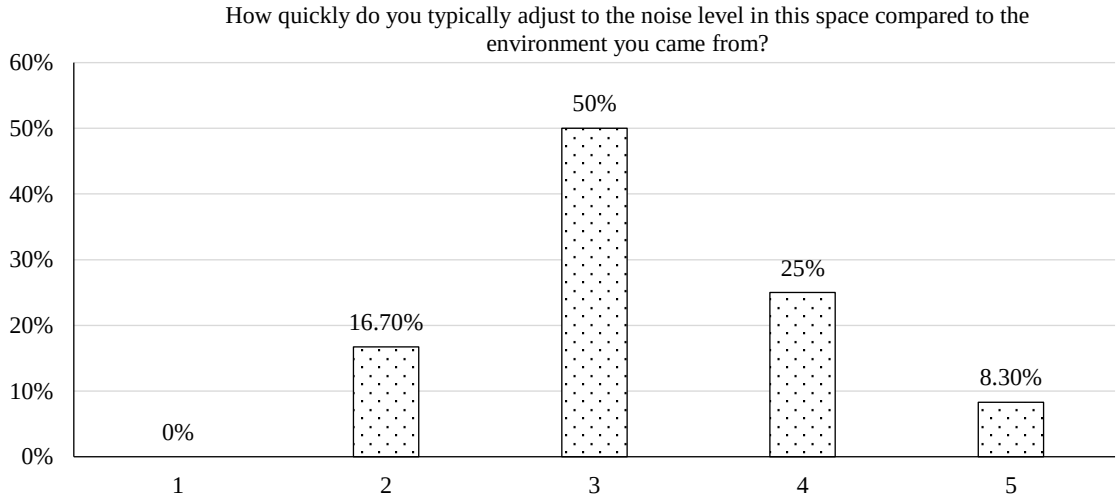

Figure 12. Ease of adjusting to the noise level.

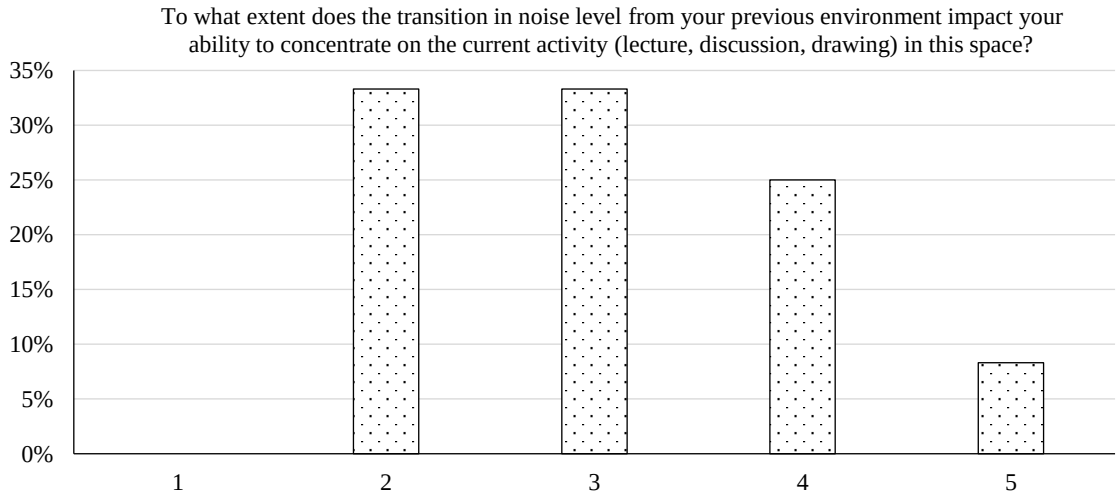

Figure 13. Transition of noise level affecting the ability concentrate.

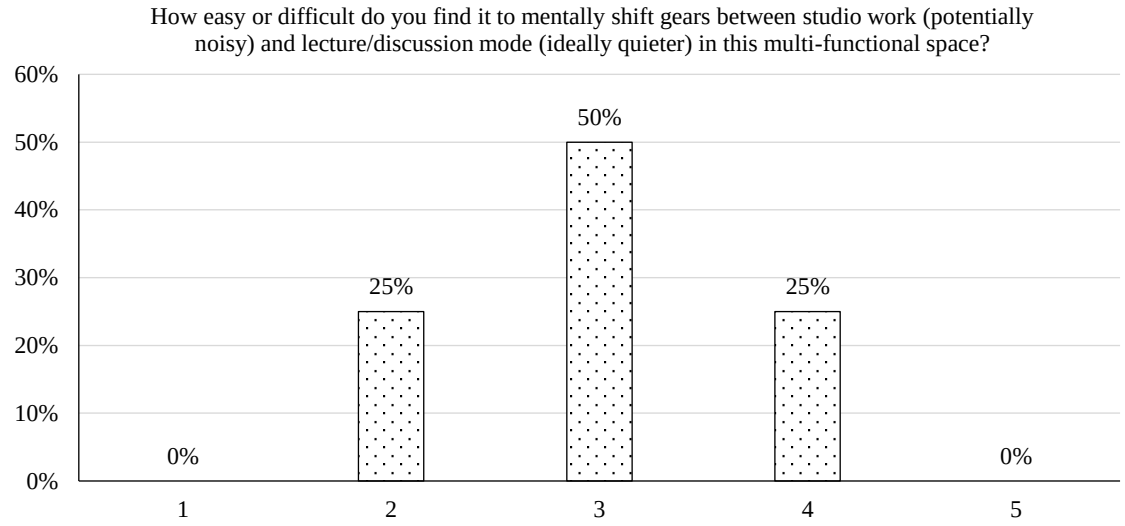

Figure 14. Ease or difficulty in shifting mental gears between studio work and lecture.

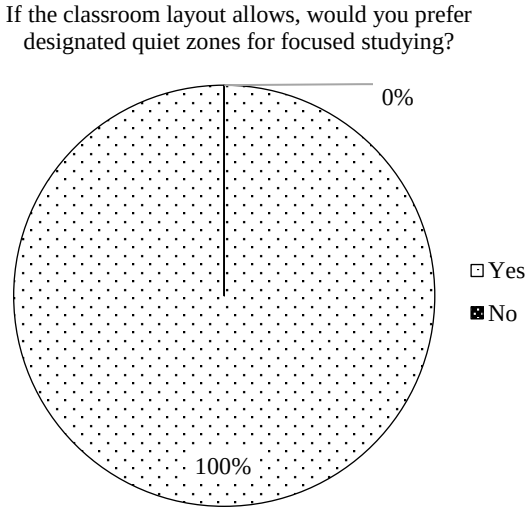

Figure 15. Students in favor of designated quiet zones in classroom.

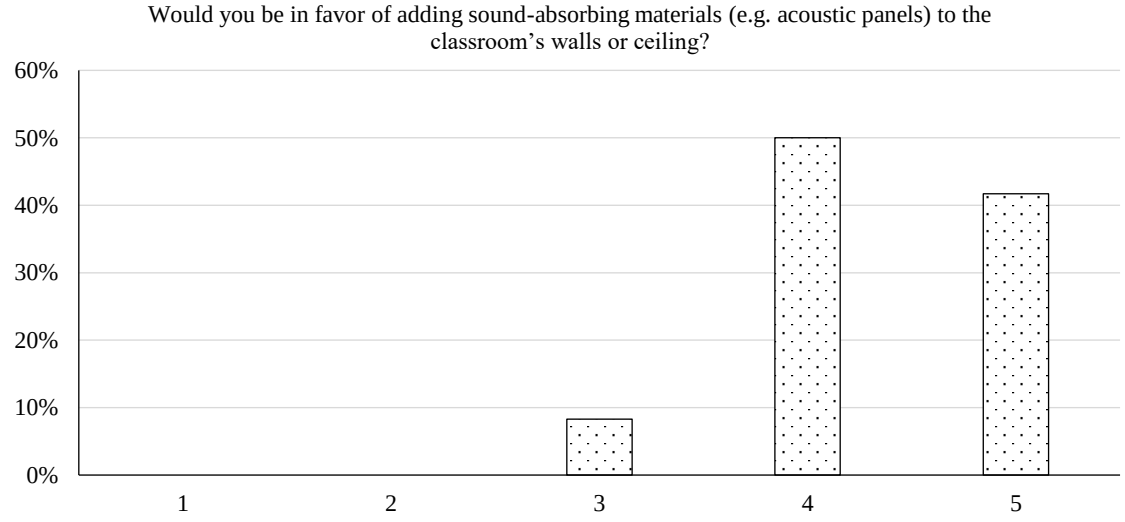

Figure 16. Students in favor of adding sound-absorbing materials.

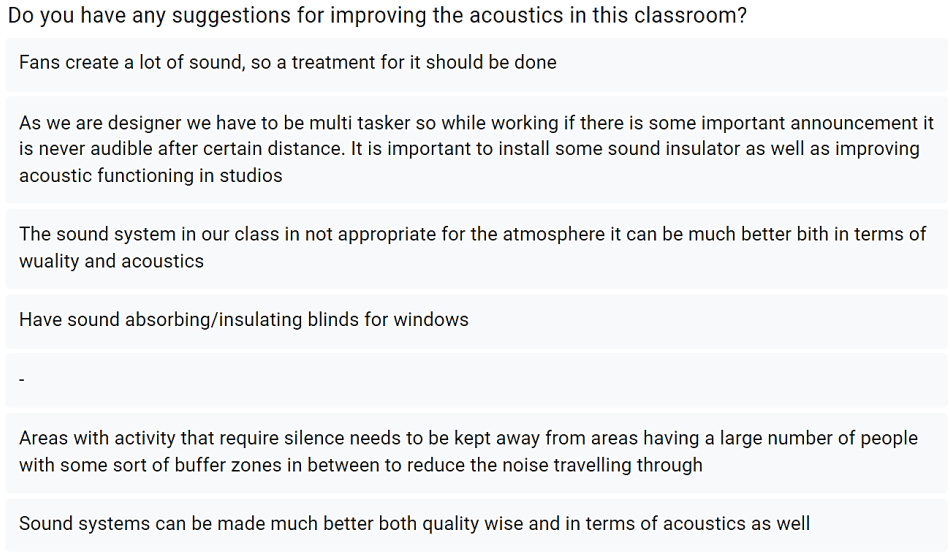

Figure 17. Suggestions from students to improve the soundscape of classroom.

The survey enlisted the following set of issues that creates hindrance and unfavorable studying conditions (Figures 15–17):

- Echo and reverberation
- Excessive background noise from outside the classroom (Traffic, hallway noise, noise from neighboring studios, etc.)
- Noise from within the classroom (Fan noise, furniture movement, etc.)
- The backbenchers have difficulty hearing the instructors
- The quality of audio–visual equipment
- Lack of sound-absorbing materials
- Lack of acoustical awareness

From the analysis of built environments such as building location, surroundings and Architectural parameters that includes, room dimensions (Figure 18), furniture layout, audio-visual equipment, and materials, following observation data was collected:

- *Noise sources*:
  - *External noise sources:* Frequent vehicular movement along the campus road (Figures 19–24) vehicle movement in parking lot (Figure 25) and sound from functions conducted in Chanakya lawn (Figure 26) that creates unnecessary disturbances and distractions.
  - *Noise within the building:* Sounds coming from other studios especially when microphones are used for conducting lectures and presentations and sometimes staff and students chattering as they pass through the corridor.
- *Floor layout*: Each floor consists of 3 to 4 studios (2 architecture and design studios, remaining lecture classrooms/design workstations), cabins for teachers, staff room and pantry, lobby attached to all studios, 2 staircases, lift area and toilets (Figure 18).
- *Studio layout*: The studio spaces comprise of architectural tables and stools placed at regular intervals. A podium for the instructor is placed at the front corner of the class. The rooms are spacious resulting in increased echo and reverberation (Figures 27–29).
- *Windows and curtain in Studios*: The studios have glass panel windows (no sound insulation), where only some studios have light curtains (very low sound insulation) for the windows. Glass panels add to the sound-reflective surfaces.
- *Sound transmission*: The common wall shared by studios and corridor have glass paneling (no sound insulation) making it susceptible to sound transmission (Figures 30–32). The same goes with glass paneled cabins. Stairwell amplifies the noise around and creates disturbances (Figures 33 and 34)

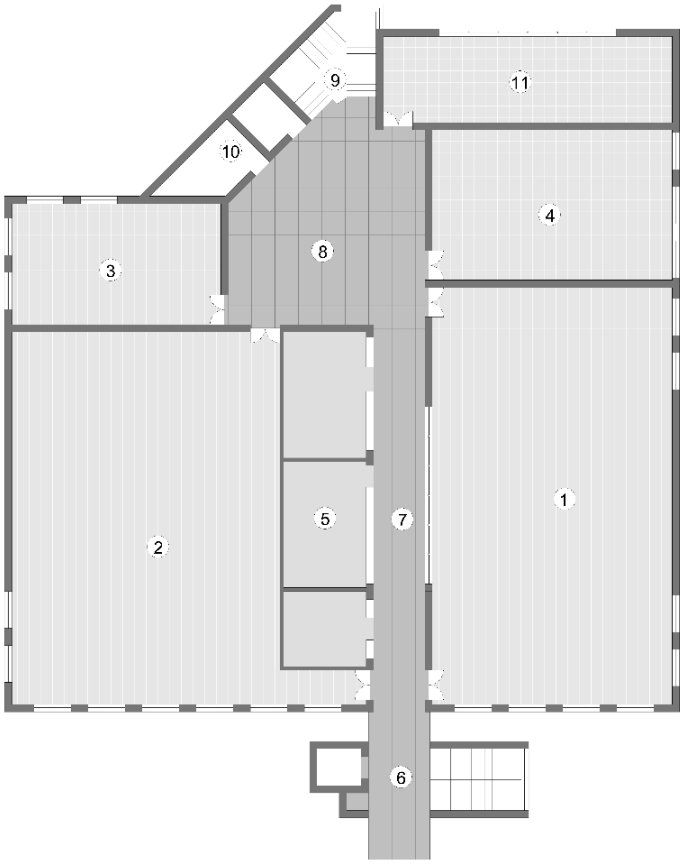

Figure 18. Typical floor plan: (1) Studio A, (2) Studio B, (3) Studio C, (4) Lab, (5) Teacher's cabin, (6) Lift lobby, (7) Corridor, (8) Lobby, (9) Staircase, (10) Toilets, (11) Common room.

Figure 19. Front view of the vastu building.

Figure 20. Campus road running in front of the building.

Figure 21. Left side setback.

Figure 22. Rear side, Charak, Pharmacy Dept.

Figure 23. Rear setback from Charak

Figure 24. Right side setback.

Figure 25. Parking along the right setback.

Figure 26. Campus road leading to Chanakya lawn.

Figure 27. Studio A internal view.

Figure 28. Studio B internal view.

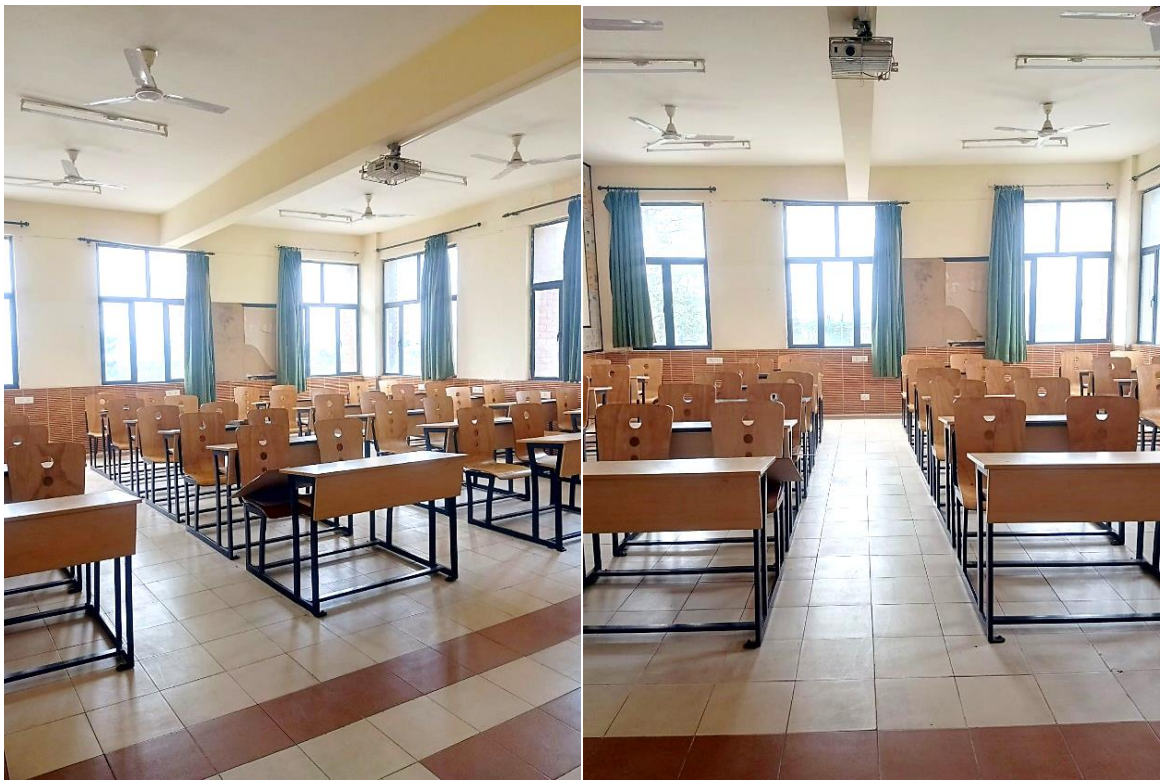

Figure 29. Studio C internal view.

Figure 30. Teacher's cabin along the corridor.

Figure 31. (a) Corridor view from lift area to lobby (left), (b) view from lobby to list area (right).

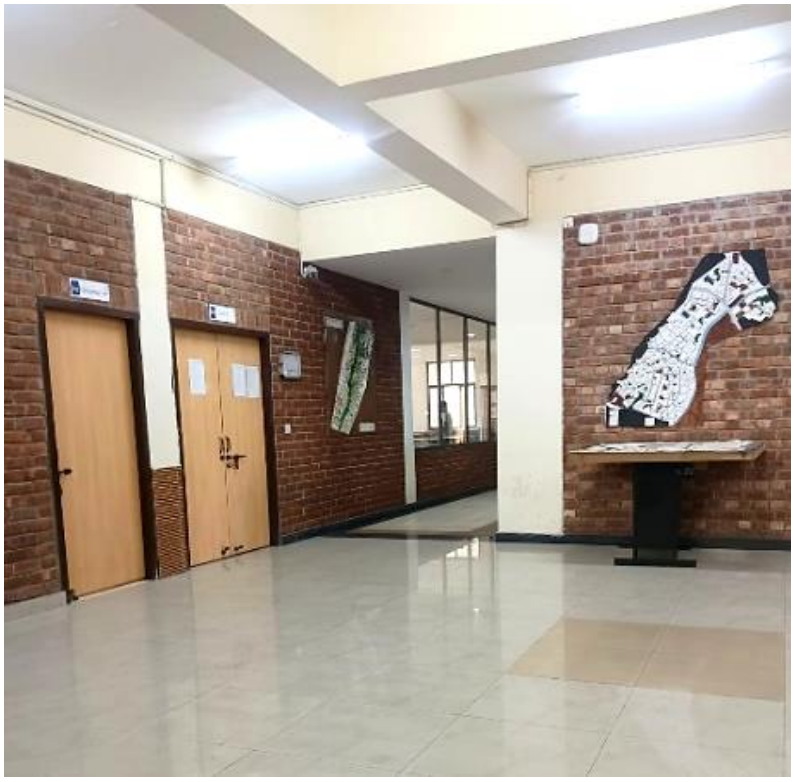

Figure 32. Lobby area.

Figure 33. Lobby stairwell.

Figure 34. Lift lobby with staircase.

- *Sound reflecting surfaces within the studios*: Walls, ceilings, ceramic tiled flooring, windowpanes, and glass partition. Some portions of the walls are covered by cork bulletin boards, known for their sound-absorbing quality, but not much helpful in reducing echoes considering the volume of the studios.

DISCUSSION

The main objective of this survey was to understand the perspective of students toward the learning spaces in relation with their psychological behavior and the issues they face regarding the acoustical ambience. Major issues faced were Background noise level (external and internal), distance from the instructor, lack of sound-absorbing material, need for better quality audio–visual equipment and the psychological state of the students. Based on the survey some remedies/solutions may be adopted for better soundscape and learning experience.

Sound-Absorbing Materials

This option will cater for the issues relating to echo, reverberation, and excessive noise produced from outside and inside the classroom.

- *Heavy curtain*: These are thick, sound-absorbing curtains made with materials like Velvet, Velcro, and other sound-absorbing fabrics, that help in blocking noise from entering the classrooms (Figure 35).
    - *Carpeting and rugs:* For significant absorption of sound, carpeting on the classroom floors could be done. Areas with high movements such as corridors can reduce the overall background noise compared with hard surfaces like tiles (Figure 36).
    - *Acoustic panels:* These are sound-absorbing panels which attach to the walls and ceilings of the space to provide more acoustical insulation. Within the classroom layout it would be preferred to place these panels on the wall and ceiling behind the presenter/instructor ensuring their voice doesn't get distorted within the space (Figure 37).

Figure 35. Sound-absorbing curtain.

Figure 36. Textured carpet.

Figure 37. Acoustic panels for wall and ceiling.

Figure 38. Window seals.

Sound Blocking Materials

This method will cater to the problems relating to outside noise transmission.

- *Window and door seals:* These are rubber/foam gaskets which ensures a tight seal around the window or door perimeter providing a better sound insulation (Figure 38).

Classroom Configurations

- *Classroom layout*: By separating furniture for discussions and lectures from the other furniture used for studio activities like drafting, model making, and so forth. A temporary curtain system can be installed between these furniture separations which would reduce the sound transmission.
- *Minimized reflective surfaces*: Avoiding large bare walls or hard surfaces which can reflect sound and cause acoustical issues such as reverberation and echo.

Acoustical Technologies

- *Sound masking systems*: These are a set of systems that incorporate machinery that generates custom sound profiles which help in masking and reducing other unwanted noises produced within or outside the classroom (Figures 39 and 40).

Directional Microphones and Speakers

Utilizing microphones that mainly focuses on the voice of instructor. The speakers could be strategically placed such that the sound is projected toward the back of the classroom.

- *Upgrade in audio equipment*
  - Investing in high-quality microphone that can captures the voice of the instructor clearly.
  - Ensuring that the speakers are of proper size and are positioned according to the classroom layout.
  - Utilizing the audio processing systems which help in equalizing and noise reduction and enhances speech clarity.
- *Lavalier microphones*: These are wireless clip-on microphones that could be positioned closer to the mouth for improved voice capturing and increased mobility of the instructor (Figure 41).

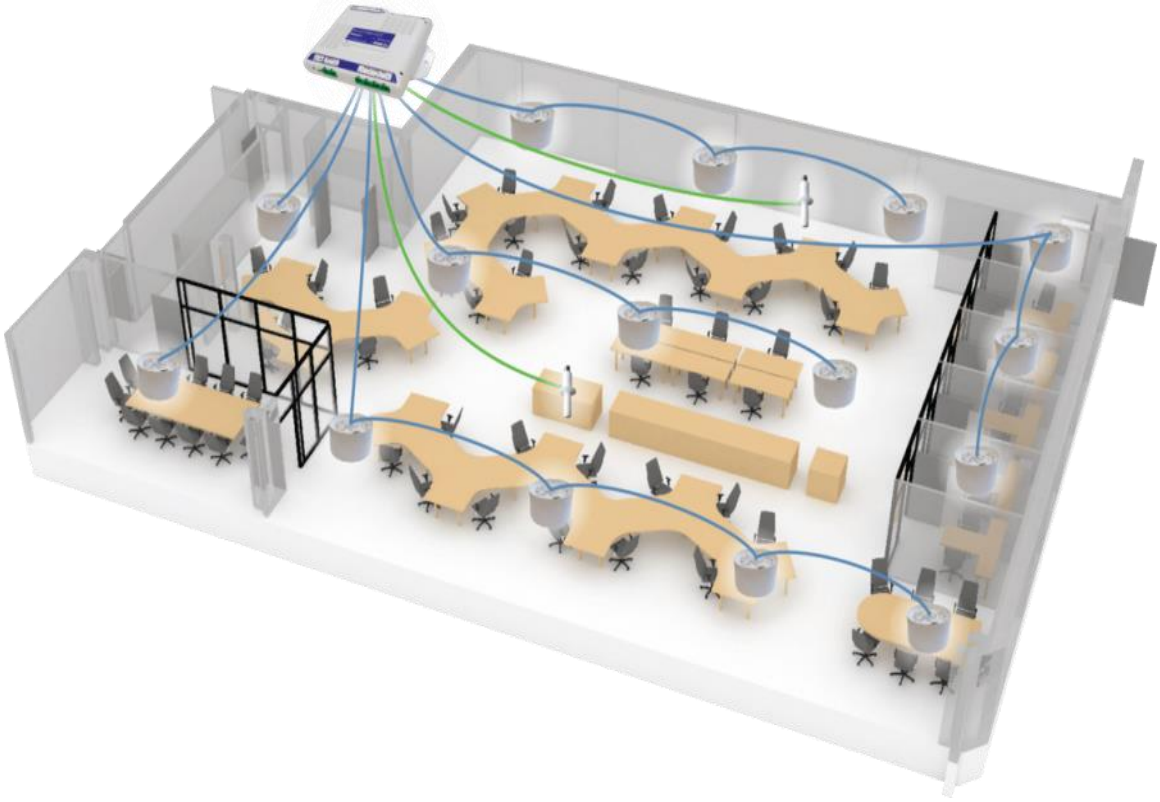

Figure 39. Smart SMS-NET (sound masking system).

Figure 40. Active volume control sensor, ceiling speaker, compact controller.

Figure 41. Lavalier microphone.

CONCLUSION

The objective of this study was to understand the scope of technology and material in the field of personalization in educational spaces, specifically the lecture halls for architectural learning and studio work. Also, understanding the perception and psychological state of the students in regards to their surrounding soundscape and how that affects their learning process. This article mainly deals with existing built spaces, which may require some fine adjustments and sound tuning for better functioning and acoustical comfort. The existing built environment can be customized to suit the user preferences, here to make a space more efficient in terms of acoustics to enhance the learning experience of students.

To sum up the study and analysis of this research paper, it can be concluded that acoustics play a very important role in educational spaces. Comfortable acoustics help students concentrate and learn with no difficulty in hearing the instructor, fewer distractions, and enhanced their ability to pertain the studied material. Acoustical comfort can also improve the psychological state of the students by lowering the noise level, hence lowering the audible chaos. The surveys were conducted to gain insights from the students about the current acoustical situation of the lecture hall. The analysis of the surveys conducted highlighted some areas for improvement.

Some minor changes, including the addition of sound-absorbing panels and sound masking technologies, can reduce echo and reverberation and sound transmission from one space to another. Though all the methods discussed in this article are effective in sound insulation, it is also important to have an idea of the issues one might be facing regarding sound insulation. This study is a glimpse of the general and accessible acoustical solutions that may be deployed for better acoustical comfort in the educational indoor spaces.

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