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Review Paper

The Impact of Classroom Acoustic Environments on The Behaviour of Special Needs Students: A Systematic Literature Review

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Abstract: This systematic literature review explores the impact of acoustic environments on the behaviour of special needs students, addressing a crucial gap in understanding how poor classroom acoustics affect learning and well-being. Despite growing awareness of inclusive education, limited research consolidates how optimized acoustic conditions can support behavioural and educational outcomes for this group. To address this, a structured review of articles published between 2021 and 2024 was conducted using Scopus and Web of Science. Inclusion criteria included English-language journal articles, within the final publication stage, in the social sciences domain. The review adhered to the PRISMA framework, resulting in 24 relevant studies for final analysis. Two main themes emerged: (1) the importance of acoustic quality in educational settings, and (2) strategies to improve classroom acoustic environments. The findings underscore the need for targeted interventions to create acoustically supportive classrooms that meet the cognitive, emotional, and behavioural needs of special needs students. This study offers critical insights for educators and policymakers, emphasizing that poor acoustics can heighten learning challenges. It calls for urgent revisions in educational policies, inclusive classroom designs, and implementation of evidence-based acoustic modifications to ensure equitable learning opportunities for all students, particularly those with special needs.

Keywords: Acoustic environments; special need students; classroom setting; student behaviour; noise impact

Introduction

The acoustic environment in educational settings has gained significant attention due to its profound impact on students' learning outcomes and behaviour (Levandoski & Zannin, 2022). While numerous studies have explored the general effects of noise and poor acoustics on students' cognitive and academic performance, this research focusing specifically on special needs students remains limited. This is a crucial gap, as these students often exhibit heightened sensitivities to auditory stimuli due to their unique sensory, cognitive, and emotional profiles. The term "special needs" encompasses a wide range of conditions, including autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), and sensory processing disorders (Sarwendah et al., 2023; Trillo-Espinoza et al., 2023). For these students, exposure to high noise levels, excessive reverberation, and poor sound insulation can significantly disrupt concentration, communication, and emotional regulation, leading to increased stress and behavioural challenges (Mealings, 2022).

Existing research has established that optimal acoustic environments are essential for facilitating concentration and comprehension among all students (Gheller et al., 2020). However, studies have not sufficiently synthesized how classroom acoustics specifically impact special needs students' engagement, behaviour, and academic success. Furthermore, there is a lack of comprehensive analysis regarding effective intervention strategies that can mitigate the negative effects of poor acoustics in special education settings. This study seeks to bridge this gap by systematically reviewing recent research on the relationship between acoustic environments and the behavioural outcomes of special needs students.

The challenges posed by poor acoustic conditions in schools stem from both external and internal sources, such as traffic noise, playground activities, HVAC systems, and classroom chatter (Shen, Fitzgerald & Kulick, 2022). These auditory disruptions disproportionately affect special needs students, who often require additional processing time and quieter environments to understand instructions and interact effectively. Excessive noise can exacerbate their learning difficulties, contribute to heightened anxiety, and even trigger disruptive behaviours such as aggression or withdrawal (Mealings & Buchholz, 2024). Addressing these challenges requires a multifaceted approach, including improved classroom design, sound-absorbing materials, and technological interventions such as FM systems and sound field amplification. Additionally, teacher training and awareness are critical to implementing effective classroom management strategies that minimize auditory stressors.

Given the increasing emphasis on inclusive education, understanding and improving acoustic conditions in classrooms has become more relevant than ever. With growing enrolments of special needs students in mainstream schools, policymakers and educators must prioritize strategies that create acoustically supportive learning environments. This review contributes to the field by synthesizing existing research on this issue, identifying key themes, and offering evidence-based recommendations for educators, school administrators, and policymakers. By fostering greater awareness and implementing targeted interventions, we can enhance not only the educational experiences of special needs students but also promote equity and inclusivity in education. The research question is as below:

i. What are the importances of acoustic quality in educational settings to students with special need behaviours?
ii. How to improve the acoustic environment in classroom?

Literature Review

The acoustic environment in educational settings plays a critical role in shaping students' behaviour and academic achievement, with a notably intensified effect on students with special needs. While previous studies extensively document the detrimental influence of poor acoustics on learning outcomes, significant gaps persist in understanding the differences across cultural and economic contexts, as well as the effectiveness of various interventions. This literature review critically examines existing research, identifying consistencies, contradictions, and contextual limitations in the field.

Poor acoustic conditions, compounded by inadequate thermal and air quality, have been widely recognized to disrupt teaching and learning processes (Brink et al., 2024). El Yamlahi Chahdi et al. (2024) similarly highlight the problem of excessive noise in Moroccan schools due to external factors like traffic and markets, where noise levels exceed normative standards. However, both studies predominantly focus on general student populations and largely overlook the specific vulnerabilities of special needs students, signalling a notable limitation in the scope of current research.

Strategies for coping with classroom noise among primary school children have also been explored, emphasizing how students with lower working memory capacities are disproportionately affected (Massonnié et al., 2022). Yet, Massonnié et al.'s study is restricted by its lack of attention to cultural and infrastructural variability, which Todorov et al. (2022) address by examining the experiences of deaf or hard-of-hearing (DHH) students. Todorov et al. reveal that background noise significantly hampers DHH students' participation, underlining the critical need for assistive listening devices. However, their successful implementation in developed nations contrasts sharply with the challenges faced by resource-constrained educational systems, revealing inequalities in intervention accessibility.

Global disparities further surface in how noise challenges are managed. For example, Folkerts (2023) identifies how seemingly minor noises like paper rustling can induce stress and impair cognitive functioning, particularly in English as a Foreign Language (EFL) classrooms. Similarly, Chapman et al. (2023) demonstrate the Quiet Classroom Game's success in reducing classroom noise. Nevertheless, the broader applicability of such behavioural interventions across multilingual and resource-limited environments remains questionable. Irish (2022) further complicates the picture by showing that while specialized designs like withdrawal rooms benefit students with autism, such infrastructural innovations are not feasible in low-income schools, highlighting the tension between best practices and contextual realities.

Technological solutions offer promising, yet uneven, advances in addressing acoustic challenges. Ogbuagu et al. (2023) advocate for Diffuse Ceiling Ventilation (DCV) systems to simultaneously improve thermal and acoustic conditions, a solution suitable primarily for schools in extreme climates with adequate resources. Bottalico et al. (2023) reinforce the broader benefits of improved acoustics for both students and teachers, particularly for educators with voice disorders. Nonetheless, the feasibility of implementing such advanced ventilation and acoustical enhancements remains questionable in economically disadvantaged educational settings.

Socioeconomic background also significantly mediates the effects of classroom acoustics. Carlie et al. (2024) demonstrate that background noise disproportionately affects bilingual and low-socioeconomic status students' narrative listening comprehension, a finding aligned with Hu et al. (2022), who employ micro-expression analysis to assess acoustic comfort. These studies illustrate that while technological innovations for measuring acoustic impact are advancing, they are predominantly tested and validated in relatively well-resourced contexts, limiting their immediate applicability in underprivileged schools.

Behavioural and environmental interventions demonstrate consistent benefits but are not without limitations. García-Real et al. (2024) argue that addressing classroom noise improves both teacher well-being and student outcomes, while Falcon et al. (2023) link teacher speech emotional intensity to student motivation under optimal acoustic conditions. However, these interventions may not easily translate into systems where teachers already face high workload stress and resource shortages, raising questions about the sustainability of such approaches.

Acoustic optimization is essential for cognitive development and speech comprehension, but again, implementation varies widely. Razali et al. (2023) stress that unfavourable acoustics hinder long-term academic success, whereas Lileikyte et al. (2022) highlight the role of sound field amplification and structured monitoring. Although cost-effective surface treatments are proposed, financial and logistical barriers remain significant obstacles for widespread adoption in developing educational systems. Frameworks like the ASPECTSS Design Index propose structured interventions for autism-friendly spaces (Mostafa et al., 2023). Their effectiveness is evident in developed educational settings but is tempered by the financial realities that make such comprehensive designs unattainable elsewhere. Similarly, Ludyga et al. (2022) reveal that moderate-to-vigorous physical activity (MVPA) mitigates off-task behaviour, suggesting that movement-based strategies could complement acoustical interventions. Yet, physical activity integration may be constrained by rigid curricula and limited classroom spaces in many school environments.

Finally, technological innovations for training and classroom design, such as VR simulations for managing noise (Remacle et al., 2023) and the regulation of visual stimuli (Godwin et al., 2022), present forward-thinking strategies. However, the transferability of such technologically intensive interventions to under-resourced settings is highly limited, further widening the gap between best practices and real-world feasibility. fIn conclusion, while the reviewed literature robustly affirms the significant role of acoustic environments in shaping special needs students' behaviour and learning outcomes, the broader comparative analysis reveals important contradictions and contextual limitations. Many effective strategies are demonstrated in well-funded, technologically advanced environments but are difficult to replicate in lower-resource settings. Future research must therefore prioritize the development of scalable, adaptable, and affordable acoustic solutions to ensure that interventions are not only effective but also contextually viable across different educational landscapes.

Methodology

1. Research Design

This article is a systematic literature review design, which involves a structured and comprehensive process of identifiying, selecting, analyzing and synthesizing relevant studies from academic database to explore the impact of classroom acoustic environments on student behavior, ensuring a clear understanding of existing research trends and gaps.

2. Identification

The identification of multiple pertinent publications for this investigation entailed the utilization of three fundamental phases of the systematic review procedure. By employing dictionaries, thesauri, encyclopedias, and previous studies, analogous terms were identified for the keywords chosen in the initial phase. All pertinent keywords were chosen subsequent to formulating search queries for both Scopus and WoS (refer to Table 1). Scopus and Web of Science (WoS) were selected for this review due to their global recognition for indexing high-quality, peer-reviewed academic sources. Scopus provides extensive multidisciplinary coverage, including acoustics, education, and social sciences, while WoS is known for its rigorous indexing standards and citation tracking capabilities. Other databases were considered but excluded, for example, Google Scholar and ERIC. In the initial phase of the systematic review procedure for the present research project, a total of 1642 articles were successfully obtained from both databases.

Table 1. The search string

Scopus	TITLE-ABS-KEY (classroom AND (noise OR reverberation OR acoustic) AND (behaviour OR action OR attitude OR performanc e)) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024)) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final"))
Wos	classroom AND (noise OR reverberation OR acoustic) AND (behaviour OR action OR attitude OR performance) (Topic) and 2024 or 2023 or 2022 or 2021 (Publication Years) and Article (Document Types) and English (Languages) and Education Educational Research (Research Areas)

3. Screening

The collection of possibly relevant research items is examined for content that matches the predefined research question(s) during the screening step. Content-related criteria that are frequently used in the screening phase include the selection of research items based on the classification of environment management and special education. In this step, all duplicate papers will be removed from the list of searched papers. The first stage of the screening excluded 1584 publications, while the second stage examined 58 papers based on different exclusion and inclusion criteria of this study (see Table 2). Literature (research papers) was the first criterion utilized because it is the primary source of practical recommendations. The article includes all types of studies that provide empirical data, including experimental research that evaluates the direct impact of noise reduction interventions, observational studies that analyze naturally occurring classroom acoustic conditions and case studies that offer in-depth insight into specific educational settings.

It also includes English, 2021-2024, Journal (Article), Final, Sosial science that were not included in the most recent study. Furthermore, the review was confined to publications in English. It is vital to remember

that the strategy only focused on the year 2021- 2022. In all, 7 publications were rejected based on duplication criteria.

Table 2. The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2021-2024	< 2021
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject area	Sosial science	Others

4. Eligibility

The final review sample is generated after all inclusion and exclusion criteria have been met. A thorough disclosure of the full list of research items included in this sample is required, since readers will not know which research items exactly form the foundation for the review's study results otherwise. The third level, termed eligibility, includes 51 articles in total. At this point, all article titles and significant content were carefully examined to ensure that the inclusion criteria were met and that the articles were relevant to the present study's research aims. Consequently, 28 publications were excluded, since their title and abstract were not significantly related to the study's purpose based on empirical data. Ultimately, 23 papers were made available for review.

5. Data Abstraction and Analysis

An integrative analysis was used as one of the assessment strategies in this study to examine and synthesise a variety of research designs (quantitative, qualitative, and mixed methods). The goal of the competent study was to identify relevant topics and subtopics. The stage of data collection was the first step in the development of the theme. Figure 2 shows how the authors meticulously analysed a compilation of 23 publications for assertions or material relevant to the topics of the current study.

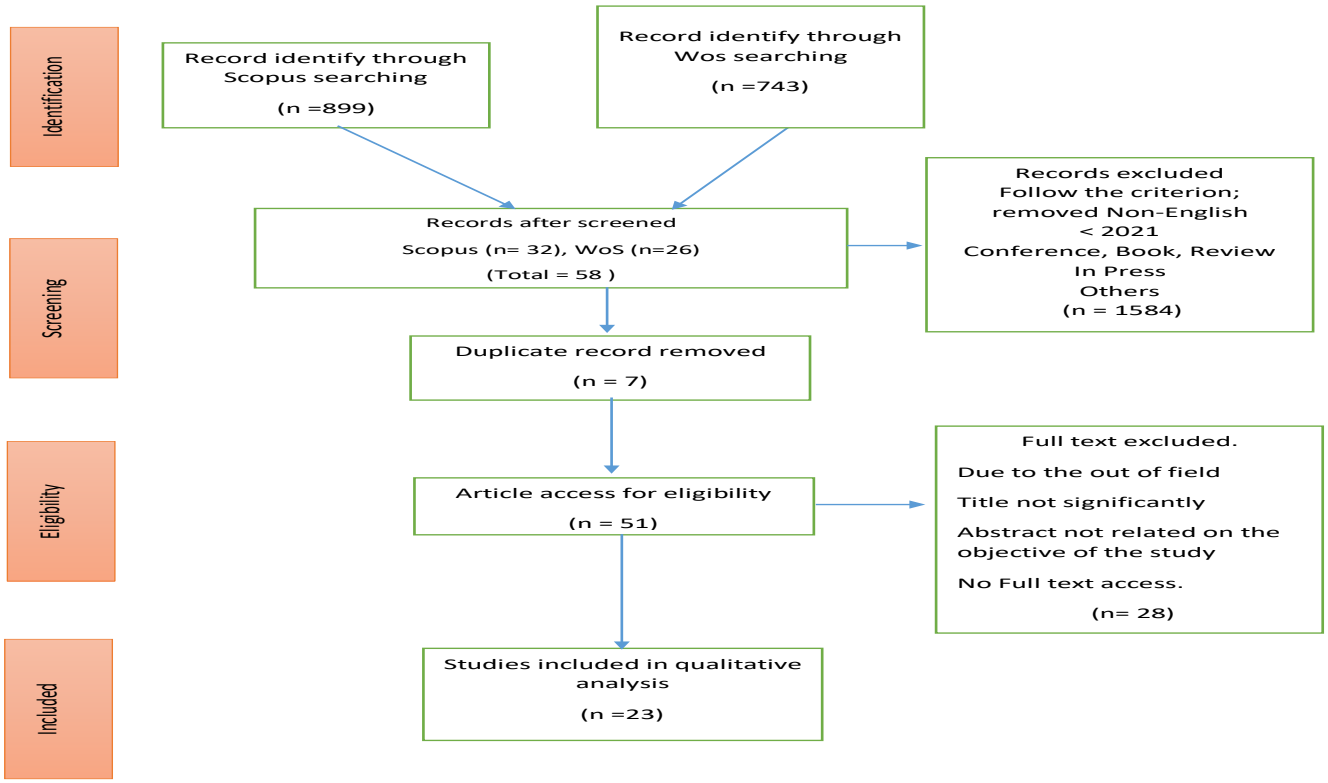

Figure 1. Flow diagram of the proposed searching study

The authors then evaluated the current significant studies related to acoustic environment and effect on special needs student's behaviour. The methodology used in all studies, as well as the research results, are being investigated. Next, the author collaborated with other co-authors to develop themes based on the evidence in this study's context. A log was kept throughout the data analysis process to record any analyses, viewpoints, riddles, or other thoughts relevant to the data interpretation. The authors compared the results to see if there were any inconsistencies in the theme design process. It is worth noting that, if there are any disagreements between the concepts, the authors discuss them amongst themselves. The produced themes were eventually tweaked to ensure consistency. The analysis selection was carried out by two experts, one in special education and the other in audiology, to determine and determine the validity of the problems. The expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity

The Finding and Discussion

The findings were organized into two main themes based on the research question.

1. The importance of Acoustic Quality in Educational Settings to Students with Special Need Behaviours

The acoustic environment in classrooms significantly influences the behaviour and learning outcomes of students, particularly those with special needs. Effective classroom acoustics minimize distractions, improve focus, and foster engagement, whereas poor acoustics exacerbate behavioural issues, especially for children with sensory processing challenges. Numerous studies highlight the importance of acoustic quality in education and the necessity for targeted interventions to accommodate students with special needs.

Noise pollution is a major factor affecting student attention and behaviour. El Yamlahi Chahdi et al. (2024) found that excessive noise in schools hampers students' ability to concentrate and perform academically, with a more pronounced effect on students with sensory sensitivities. Bottalico et al. (2023) further demonstrated that students struggle to comprehend lessons when teachers have a dysphonic voice, an issue that is particularly detrimental for those with auditory processing difficulties. These findings emphasize the necessity of optimizing classroom acoustics through sound-absorbing materials and noise-reducing strategies to support positive behavioural outcomes (Remacle, A.,2023).

Beyond noise control, classroom ventilation systems also play a crucial role in shaping the acoustic environment and, in turn, student behaviour. Research by Ogbuagu et al. (2023) on diffuse ceiling ventilation systems highlighted that poor ventilation amplifies noise levels, increasing off-task behaviour. Optimizing ventilation can reduce background noise and enhance classroom dynamics, benefiting students who are particularly sensitive to auditory disruptions. Similarly, balancing thermal comfort with acoustics is essential, as Lamberti et al. (2021) pointed out that both temperature and noise influence students' concentration and behaviour. This highlights the need for a holistic approach to classroom design, integrating both thermal and acoustic considerations to create a supportive learning environment.

Students' responses to noise vary, influenced by factors such as sensory processing differences, cognitive adaptability, and prior exposure to noise. Godwin et al. (2022) noted that students in well-managed acoustic environments demonstrate better attention allocation, particularly those with attention-related challenges. However, Chapman et al. (2023) found that structured interventions, such as the Quiet Classroom Game, can help students self-regulate and improve on-task behaviours. These findings collectively suggest that while some students may develop adaptive coping mechanisms in response to noisy settings due to either neurological resilience or environmental exposure others require proactive interventions to thrive. The educational implication here is clear: one-size-fits-all acoustic solutions are insufficient. Instead, schools must adopt a differentiated environmental management approach, tailoring strategies to support the full spectrum of learner needs.

In summary, classroom acoustics significantly impact student behaviours, particularly among those with special needs. Noise reduction strategies, ventilation optimization, and structured interventions such as the Quiet Classroom Game are crucial in fostering a learning environment conducive to better behavioural and academic outcomes. Recognizing individual differences in noise sensitivity is essential for designing

classrooms that accommodate diverse learning needs, ensuring that students receive the necessary support to thrive in an acoustically optimized setting.

2. Improving The Acoustic Environment In Classrooms

Improving the acoustic environment in classrooms is crucial for enhancing students' attention, communication, and overall learning outcomes, particularly for those with special needs. Background noise, classroom materials, and teaching methodologies all contribute to the effectiveness of learning environments. Addressing these challenges requires a comprehensive approach that integrates noise reduction strategies, technological innovations, and structured learning activities.

The impact of noise on cognitive and communication skills is well-documented. Carlie et al. (2024) highlighted that background noise negatively affects primary school children's listening comprehension, with those from bilingual and lower socioeconomic backgrounds being disproportionately affected. Similarly, Morini and Newman (2021) found that toddlers struggle with word recognition in noisy environments, emphasizing the importance of sound control. These findings align with global best practices, such as Finland's acoustic regulations for schools, which mandate sound-absorbing materials and low-noise ventilation systems to create optimal learning environments (Kylliäinen et al., 2023).

Physical and structural modifications, such as using acoustic panels, carpets, and curtains, significantly reduce noise distractions. Research by Lileikyte, Irvin, and Hansen (2022) emphasizes how structured learning environments enhance communication through speech recognition technologies. In Japan, sound-masking systems have been introduced in classrooms to balance auditory input, reducing excessive noise without creating complete silence (Yoshida and Takahashi, 2023). These approaches demonstrate how tailored interventions can foster better classroom engagement.

Virtual learning environments also present promising solutions. Remacle, Bouchard, and Morsomme (2023) found that teaching simulations in virtual classrooms enhanced teachers' oral communication skills and self-efficacy. Similarly, virtual reality (VR) classrooms have been successfully implemented in Denmark, where VR-based speech training tools help students with auditory processing difficulties (Andersen & Nielson, 2023). These technologies provide adaptive learning experiences that can be applied to physical classrooms.

Beyond noise reduction, active learning methods and physical activity contribute to better classroom behaviour, indirectly improving acoustic conditions. Ludyga et al. (2022) found that moderate-to-vigorous physical activity positively influenced student attention and reduced disruptive behaviours. Schools in Canada have integrated movement-based learning to create more engaged and quieter classroom settings (Smith et al., 2023). These findings suggest that structured movement activities can serve as dual-purpose strategies for managing both behaviour and noise levels.

Ultimately, technology integration offers a modern approach to optimizing classroom acoustics. Kang et al. (2024) explored the role of virtual musical instruments in fostering controlled auditory experiences in music classrooms. Similarly, schools in Sweden have implemented real-time classroom sound monitoring systems that alert teachers when noise levels exceed optimal thresholds (Eriksson and Lindholm, 2023). These interventions highlight how digital tools can enhance the learning environment while mitigating excessive noise.

Crucially, many of the strategies highlighted across countries Finland's acoustic mandates, Japan's sound-masking innovation, Sweden's noise-monitoring tools are rooted in well-resourced systems. Translating these interventions to contexts like Malaysia, or other developing nations, demands local adaptation and prioritisation. For example, low-cost alternatives such as repurposed fabric panels, egg cartons for noise absorption, or creative classroom zoning can emulate the effects of high-end solutions at a fraction of the cost. The key lies in applying the same principles of inclusive design even when the materials differ. The Ministry of Education Malaysia needs to enhance the learning environment to help develop students' character, preparing them to become the future leaders of the nation (Wan Muda, W. M, et al., 2022).

In conclusion, creating an acoustically conducive classroom is not the domain of architects or engineers alone; it is an interdisciplinary educational challenge. By integrating physical interventions, active

learning methodologies, and adaptive technologies, schools can craft soundscapes that promote focus, equity, and well-being. More importantly, acoustic optimization must be seen not as an isolated upgrade but as a foundational commitment to inclusive education. For students with special needs who often experience sound not as neutral, but as overwhelming the difference between a chaotic and a well-managed acoustic environment can be the difference between withdrawal and participation, frustration and progress. A truly inclusive classroom is not only one that accommodates difference, but one that proactively designs for it and acoustics must be part of that design.

Conclusion

The acoustic environment in classrooms plays a crucial role in shaping the behaviour and learning outcomes of students, particularly those with special needs. Effective acoustic management reduces distractions, enhances focus, and fosters greater engagement, while poor acoustics contribute to behavioural challenges, particularly for students with sensory sensitivities. To address these issues, educators should implement structured noise-reduction strategies such as classroom sound zoning, structured quiet periods, and noise-minimizing activities to improve student attention. Policymakers must prioritize acoustic guidelines in school infrastructure policies, ensuring compliance with noise-reduction standards in new and existing classrooms. School architects should integrate sound-absorbing materials, optimized ventilation systems, and quiet HVAC solutions to create learning spaces conducive to student well-being.

In the long term, these recommendations will contribute to the development of more inclusive educational environments, where students with special needs can thrive without the added stress of excessive noise. Future policies should incorporate acoustic design principles into school construction and renovation projects, ensuring sustainable and effective learning environments. Additionally, further research should explore the intersection of acoustics with other environmental factors, such as lighting and air quality, to develop holistic strategies for optimizing classroom conditions. By taking a proactive approach, stakeholders can enhance student learning experiences and overall academic success.

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