

Perception of indoor and outdoor school soundscapes: A large-scale Cross-Sectional survey with UK teachers

Hatice Kurukose Cal, Francesco Aletta^{*}, Jian Kang

Institute for Environmental Design and Engineering, University College London, United Kingdom

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ABSTRACT

This study explores variations in teachers' perception of indoor and outdoor soundscapes across different spaces within schools. A quantitative research design involved 452 teachers in the United Kingdom who participated in an online questionnaire. The questionnaire was distributed to UK teachers via random sampling on the Prolific platform, utilizing its customizable demographics for participant recruitment. A multi-method approach, combining closed- and open-ended questions, captured the multifaceted nature of soundscape perception. Participants reported on perceptions and experiences of school soundscapes in general areas, classrooms, hallways, dinner halls, playgrounds, and gyms. Findings reveal that schools are perceived as dynamic environments, characterized by a blend of chaos, engagement, and excitement, contradicting expectations of a calm atmosphere. Correlation analysis demonstrated weak associations between age and perceptions of the acoustic environment ($r_s([452])=[0.116]$), as well as gender ($r_s([450])=[0.060]$), teaching experience ($r_s([450])=[0.117]$), school type ($r_s([450])=[-0.109]$), school location ($r_s([450])=[0.098]$), time spent in outdoor places ($r_s([450])=[0.09]$). A significant positive correlations were observed between wellbeing and the overall school soundscape ($r_s([450])=[0.286]$), indicating that as self-reported wellbeing increases, the perceived quality of the school soundscape tends to increase. Differences were seen in the soundscapes of playgrounds, dinner halls, gyms, hallways, and classrooms compared to the overall school soundscape. These distinctions highlight varying levels of engagement, comfort, intrusiveness, and privacy across different areas, emphasizing the multifaceted nature of sound perception within schools. The study shows teachers use sound in education for different reasons and methods, with perceived impacts on student learning and wellbeing. It suggests the possibility of enhancing the educational experience through tailored interventions targeting specific areas in schools based on their unique soundscapes.

1. Introduction

The acoustic environments of school facilities should guarantee that educational activities can be carried out without discomfort due to external and/or internal noise, for both staff and students [1,2]. Poor classroom acoustics can lead to negative impacts on students' learning and wellbeing [3]. Shield and colleagues provided insights into the acoustic conditions in primary school classrooms, indicating that noise levels can vary depending on the activities taking place [4]. Astolfi and colleagues assessed the subjective and objective environmental quality in classrooms involving 1,006 high school students, revealing how reverberation and noise levels can impact high school students' experiences in educational settings [5]. This study underscores the importance of establishing optimal acoustic conditions in classrooms to

enhance students' concentration, engagement, and overall wellbeing [5]. Apart from students, the impact of noise in school environments on teachers' health and wellbeing is a critical area of concern. Excessive noise levels can lead to stress symptoms, including tiredness, irritation, concentration problems, and sleeping issues, affecting teachers' overall mental and emotional health [3]. The acoustic quality of classrooms and its impact on teachers' vocal and hearing health is also a concern, highlighting the broader impact of poor acoustics within educational settings [6]. Furthermore, acoustic comfort in classrooms is essential for protecting the health and enhancing the academic performance of both students and teachers [7]. While these references touch upon teachers' wellbeing, voice disorders, and the impact of noise on them, there is a lack of specific research focusing on teachers' perceptions of the acoustic environment in schools. The existing literature primarily emphasizes

^{*} Corresponding author.

E-mail address: f.aletta@ucl.ac.uk (F. Aletta).

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students’ perception of sound, classroom acoustics, and the effects of noise on students’ learning experiences.

Although noise annoyance, disturbance, and their impact on learning remain important considerations in school acoustics, it is crucial to broaden this focus to include the overall school soundscape. This requires not only addressing noise protection but also considering all sounds, including positive ones, and finding a balance among these various sound sources. This approach refers to the comprehensive acoustic environment within educational settings, focusing not only on noise reduction but also on positive soundscapes promotion for individuals within the school environment [8]. Preliminary research on the soundscape design of schools has so far provided insights into how students perceive the acoustic environment in classrooms [9,10,8]. Comparative studies on indoor soundscape assessment in high school environments have also been conducted to understand the impact of sound on students’ experiences [11]. Additionally, research has indicated that sounds related to ventilation in classrooms can influence students’ cognition and academic performance [12]. Overall, investigating the role of soundscape in providing restorative experiences for children in indoor settings, can offer valuable insights into how everyday soundscapes influence students’ experiences and cognitive responses [13]. However, it is important that the majority of studies focus on the soundscape within classrooms, presenting a relatively narrow perspective. Therefore, understanding how the school soundscapes vary across different spaces and activities is essential for creating supportive learning environments.

Effective management of sound in schools can contribute to creating a conducive learning atmosphere that supports students’ concentration and academic performance. Research on school soundscapes emphasizes the pivotal role of sounds in children’s education, highlighting the potential positive or negative impacts of the sound environment [8]. The use of sound by teachers within educational environments represents another important point of this study, given that the existing literature does not comprehensively address this issue. While the application of sound has been identified as having potentially positive effects [14], the specific methods and strategies for its effective use remain unclear.

By considering the research gap in the study of school soundscapes, investigating the school soundscape across different spaces within schools and understanding how teachers perceive the acoustic environment can provide valuable insights into how sound influences the educational environment and teacher experiences, ultimately contributing to the enhancement of learning environments. Furthermore, there is a growing interest in understanding of how spaces such as hallways, dinner halls, and gyms within schools are perceived in terms of their overall soundscape, rather than focusing solely on the soundscape of classrooms. This approach allows for a more comprehensive examination of the school soundscape as a whole. Finally, teachers’ perceptions in school soundscape studies are often overlooked despite teachers’ crucial role in the school environment. Therefore, this study also aims to investigate their perceptions of sounds too.

The research questions considered in this study are:

- 1) How are school soundscapes overall perceived by UK teachers, considering personal and contextual factors, and how is the school soundscape affecting their wellbeing in schools?
- 2) What are the variations in indoor and outdoor soundscapes across different spaces within schools, including classrooms, hallways, dining areas, and outdoor spaces?
- 3) How do teachers proactively use sound in schools, what are the reasons behind its use, and what are the impacts on teaching and learning?

2. Methods

For this study, an online questionnaire for UK teachers was employed as the primary methodological approach to gather data on school

soundscape. The distribution of the questionnaire included 480 teachers. After the validation and data cleaning processes, 28 questionnaires were eliminated, resulting in a final sample of 452 teachers.

To ensure the validity and reliability of our online questionnaire, a pre-test was conducted with a group of volunteers. This pre-test indicated that it took at least 10 min to complete the questionnaire, establishing a baseline for the expected completion time. Based on these results, we monitored response times and excluded any responses completed in less than 10 min to ensure that respondents had sufficient time to consider their answers thoughtfully and genuinely. Additionally, rigorous data cleaning procedures were applied to remove incomplete or suspiciously uniform responses. Statistical techniques were employed to detect and address potential biases or anomalies. Descriptive statistics, such as mean, median, standard deviation, and range, were calculated to spot any outliers or inconsistencies in the data. Any response with a Z-score greater than ±3 was flagged for further examination to ensure accuracy. Correlation analyses were conducted to identify any questionable patterns in the responses that might suggest careless answering, paying close attention to unusually high correlations ($r > 0.9$) between items that should not be related. Additionally, some respondents withheld consent, thereby withdrawing from participation. As a result, twenty-eight questionnaires were eliminated after validation. Table 1 summarizes the criteria applied to filter responses during the validation and data cleaning process.

2.1. Participants

A diverse sample of 452 teachers from various educational institutions across the United Kingdom participated in this study. Random sampling was employed to ensure that the sample was representative of the population, minimizing the risk of selection bias as supported by established survey methodologies [15]. The sample aimed to represent different teaching experiences, educational backgrounds, and geographic locations within the UK. Confidence intervals were calculated to provide an estimated range for population parameters, and p-values were used to determine statistical significance, following guidelines from Cumming [16]. As shown in Equation (1), With a population of 567,309 (UK currently working teachers 2022/23 [17]), a sample size of 452 provides a margin of error of approximately 4.6 % at a 95 % confidence level. This means that we are fairly confident (95 %) that the true population parameter is within ± 4.6 % of what we found in the sample of 452 individuals. It is calculated with the formula:

$$ME = Z * \frac{\sqrt{p(1-p)}}{n} * \left(\frac{N-n}{N-1} \right) \tag{1}$$

where Z is the Z-score corresponding to the desired confidence level (1.96 for 95 % confidence), p is the estimated proportion (if unknown, 0.5 is used for maximum variability), n is the sample size. N is the population size [18]. This allows us to make reliable estimates about the population with a known level of precision and variability. Noordzij et al. [19] mentioned that the sample size for social science research usually falls between 30 and 500, supporting the adequacy of a sample size of 452 for social science studies. In principle, while the sample size may seem modest compared to the population, participants were chosen randomly to balance practical limitations with the need for accurate

Table 1
Data cleaning elimination criteria.

Exclusion Criteria	Number of Exclusions
Responses completed in less than 10 min	11
Incomplete responses	8
Uniform responses suggesting lack of effort	3
Responses with Z-score > ±3	6
Respondents who withheld consent	2
Total 28 (2 same participants)	

data. This approach allowed us to conduct a thorough analysis within the budget and timeframe, ultimately returning meaningful insights into the population’s perceptions and behaviours [20,15].

Prolific, an online questionnaire participant recruitment tool, was utilized to efficiently recruit participants, enhancing the reach and diversity of the sample [21]. In Prolific, participant demographics, including occupation, age, and country, were customizable to enable effective screening. Participant selection criteria were set to include teachers in the United Kingdom aged 18 and above. This ensured a focused and relevant sample for the research objectives.

This study received ethical approval through the low-risk procedure of the UCL BSEER (Bartlett School of Environment, Energy and Resources) Local Research Ethics Committee on 23.02.2023.

2.2. Questionnaire design

The online questionnaire, distributed via Prolific for recruitment and sampling purposes, was administered through the Research Electronic Data Capture (RedCap) platform. RedCap provides a secure and user-friendly environment for data collection [22]. Participants received a unique link to access the questionnaire, ensuring confidentiality and allowing for seamless participation at their convenience.

A structured online questionnaire was designed to gather quantitative and qualitative data on teachers’ experiences with the soundscape. The questionnaire consisted of four parts: Background Information, Sound Exposure and Perception, Wellbeing, and Soundscape of Places. The Appendix outlines the details of the questionnaires. The questionnaire encompassed both closed and open ended questions. Recognizing the complex and multi-dimensional nature of soundscape studies, a mixed-method approach was embraced [23]. This methodological merging aligns with the principle of triangulation frequently employed in behavioural and social sciences [24].

Background Information: This part of the questionnaire collects demographic information about the participants, which is essential for understanding the characteristics of the sample population. Questions include age, gender, years of teaching experience, type of school (e.g., primary, secondary), location of the school (e.g., urban, rural), and teaching environment (e.g., traditional classroom, open plan classroom). Gathering this information allows researchers to analyse how perceptions and experiences may vary across different demographic groups.

Sound Exposure and Perception: This section focuses on participants’ experiences with sounds in various school environments [25]. Participants are asked to rate the frequency with which they hear different types of sounds, such as birds singing, traffic, school bells, and children playing. Additionally, they are asked about their use of sound for teaching and supporting student wellbeing, as well as their overall perceptions of the acoustic environment in different areas of the school (e.g., classrooms, hallways, playgrounds, gyms/dining halls). This part of the questionnaire provides insights into how sounds affect teachers’ experiences and perceptions within the school setting.

Wellbeing: This section assesses participants’ perceptions of their wellbeing about their school environment. Participants responded to The Teacher Subjective Wellbeing Questionnaire (TSWQ) items were used to calculate subscale scores for teacher wellbeing [26]. TSWQ is an 8-item (See Appendix for items) self-report rating scale designed to measure teachers’ job-specific wellbeing. It comprises two subscales: School Connectedness and Teaching Efficacy. School Connectedness: This subscale assesses teachers’ sense of belonging and connection to their school environment. Teaching Efficacy: This subscale evaluates teachers’ perceptions of their effectiveness in their role as educators.

TSWQ scale scores are calculated by summing item responses as follows:

- Teaching Efficacy subscale: sum of responses to items 2, 4, 6, and 8 (See Appendix for items).

- School Connectedness subscale: sum of responses to items 1, 3, 5, and 7 (See Appendix for items).
- Teacher Wellbeing composite scale: sum of responses to all items

Soundscape of Places: This final section evaluates participants’ perceptions of the sound environment in specific areas of the school, including indoor (classrooms, hallways, dining halls, and gyms) and outdoor (playgrounds). To ensure comparability, spaces in this study are categorized according to Building Bulletin 93 Acoustic Design of Schools: Performance Standards (BB93) guidelines [27]. Teaching spaces such as classrooms, recreational and common spaces such as dining halls and gyms, and support spaces such as corridors, are functional and architectural spaces in schools. BB93 primarily focuses on indoor spaces, but to provide a comprehensive assessment of the school environment, this study also includes outdoor recreational areas, such as playgrounds. These spaces contribute to a holistic understanding of the school soundscape. Participants are asked to rate the sound environment along various dimensions for outdoors such as annoyance, eventfulness, chaos [25] and for indoors such as comfort, content, engagement [28], using Likert-scale items.

This part of the questionnaire provides detailed insights into how different areas of the school are perceived acoustically and can inform strategies for improving the overall sound environment to enhance teaching and learning experiences.

The questionnaire included both closed-ended questions and Likert-scale items, tailored to each environment (general school, classrooms, hallways, playgrounds, gyms, dining halls).

2.3. Data analysis

The questionnaire included both closed-ended questions and Likert-scale items, which necessitated the use of three different analysis methods: (1) mapping the perceptual attribute dimensions onto the circumplex model, (2) examining correlations and disparities among groups, and (3) conducting qualitative analysis. By employing these three analysis methods, the study could comprehensively explore the quantitative and qualitative aspects of the data collected through the questionnaire, leading to a more nuanced understanding of the perceptions and experiences of teachers regarding the school soundscape.

2.3.1. Mapping the perceptual attribute dimensions onto the circumplex model

The circumplex model is a circular representation that organizes complex data into a two-dimensional space. In the context of soundscape evaluation, it maps various perceptual attributes (such as pleasantness, vibrancy, calmness, etc.) onto a circular diagram. Each point’s position reflects its relationship to two primary dimensions. This approach allows for a comprehensive visualization of how different soundscapes are perceived, highlighting the interplay between various perceptual attributes and providing a nuanced understanding of the acoustic environment [29]. This study involves the perceptual attribute dimensions onto the circumplex model, separated to accommodate distinct approaches for indoor and outdoor environments. For indoor areas (classroom, dining halls, gyms, hallways, school), the scores obtained from evaluating soundscapes across eight attributes were transformed into points on circumplex models, with coordinates corresponding to the comfort and content dimensions as shown in Equations (2) and (3) [28]. Conversely, in the context of outdoor settings (i.e., Playgrounds), the emphasis is placed upon the dimensions of eventfulness and pleasantness as shown in Equations (4) and (5) [24].

The coordinates for comfort, content and pleasantness, eventfulness are calculated as:

$$\text{Content} = (p - \alpha) + \cos 45^\circ \cdot (pr - i) + \cos 45^\circ \cdot (v - d) \tag{2}$$

$$\text{Comfort} = (f - e) + \cos 45^\circ \cdot (i - pr) + \cos 45^\circ \cdot (v - d) \tag{3}$$

where α is annoying, p is comfortable, d is detached, e is empty, v is engaging, f is full of content, i is intrusive – uncontrolled, and pr is private, controlled.

$$ISO \text{ (pleasantness)} = (p - \alpha) + \cos 45^\circ \cdot (ca - c) + \cos 45^\circ \cdot (v - m) \quad (4)$$

$$ISO \text{ (eventfulness)} = (e - u) + \cos 45^\circ \cdot (c - ca) + \cos 45^\circ \cdot (v - m) \quad (5)$$

where α is annoying, p is pleasant, m is monotonous, u is uneventful, v is vibrant, e is eventful, c is chaotic, ca is calm.

These coordinates were then divided by $(4 + \sqrt{32})$ to standardise the resulting values within the range of -1 to $+1$. The Soundscapy Python package [30] was utilized for sound analysis, complemented by visualizations generated using the Seaborn plotting library [31]. This approach facilitated the exploration and visualization of sound data captured from the questionnaire, providing insights into the acoustic environment across different school locations.

2.3.2. Examining correlations and disparities among groups.

SPSS (Statistical Package for the Social Sciences) [32] was employed to conduct statistical analyses, including Spearman’s rank correlation coefficient, to assess the relationships between variables. These techniques allowed for the examination of correlations and the identification of significant relationships across groups. The sample size (n) utilized for analysis consisted of 452 participants.

2.3.3. Qualitative analysis

Transcripts of participants’ responses were subjected to thematic analysis [33]. Initially, codes were generated to capture key concepts related to the utilization of sound in schools. These codes were developed based on the content of teachers’ responses, focusing on how sound is utilized, why it is employed, and the outcomes associated with its use. Subsequently, to visualize the codes and their relationships, Vensim was utilized. Vensim is a software tool used for system dynamics modelling and simulation [34].

3. Results

In the results section, teachers’ perceptions of the school soundscape

were examined in three parts. Firstly, an overview of their overall school soundscape perception was provided. Subsequently, specific areas within the school were explored. Lastly, the utilization of sounds in the educational environment by teachers was investigated.

The online questionnaire revealed that the majority of participants, comprising 34.8 %, selected option 3 age range (35 to 44), totalling 158 respondents, while option 2 (age range 25 to 34) was chosen by 29.3 % of participants, totalling 133 respondents, 7 respondents were aged 65 and over. The majority of participants, comprising 81.6 % (370 people), identified as female, while 17.9 % (82 people) identified as male. Two participants did not specify their gender and were consequently excluded from the gender analysis. Teachers were asked about their experience in the current school where they are employed. Understanding that each school environment varies, the questionnaire aimed to assess the collective perception of the current school soundscape. Among the options, the most common duration reported was “1-5 years,” with 175 respondents, representing 38.5 % of the total. Conversely, the least common durations were “more than 20 years” and “16-20 years,” with approximately 20 respondents each, accounting for 4.4 % and “5.7 %” respectively (Fig. 1).

In this questionnaire, the types of schools where teachers are employed were investigated, which include preschool, primary, secondary, colleges, SEN (Special Educational Needs) schools, and other institutions. Primary schools emerged as the most common, with 51.5 % of respondents indicating their employment in such institutions. On the other hand, Colleges were the least commonly reported type, with the percentage of 3.8 %. Participants were asked about the location of their schools, categorized as Urban, Rural, or Semi-urban. Among the respondents, the most commonly reported school location was Urban, with 217 participants (48.0 %). Conversely, Rural locations were the least commonly reported, with 74 participants (16.4 %). The results focused on teaching spaces categorized as Traditional cellular classrooms, Multipurpose spaces, Open-plan classrooms, Learning labs or specialized rooms, Open-door policies, and Others. The most frequently selected option was the Traditional cellular classroom type, with a frequency of 322, accounting for 71.2 % of responses. In the questionnaire, the time teachers spend in outdoor areas at school were investigated, offering them several options to choose from. The responses varied, with the majority of teachers (32.5 %) reporting spending between 10 and 30

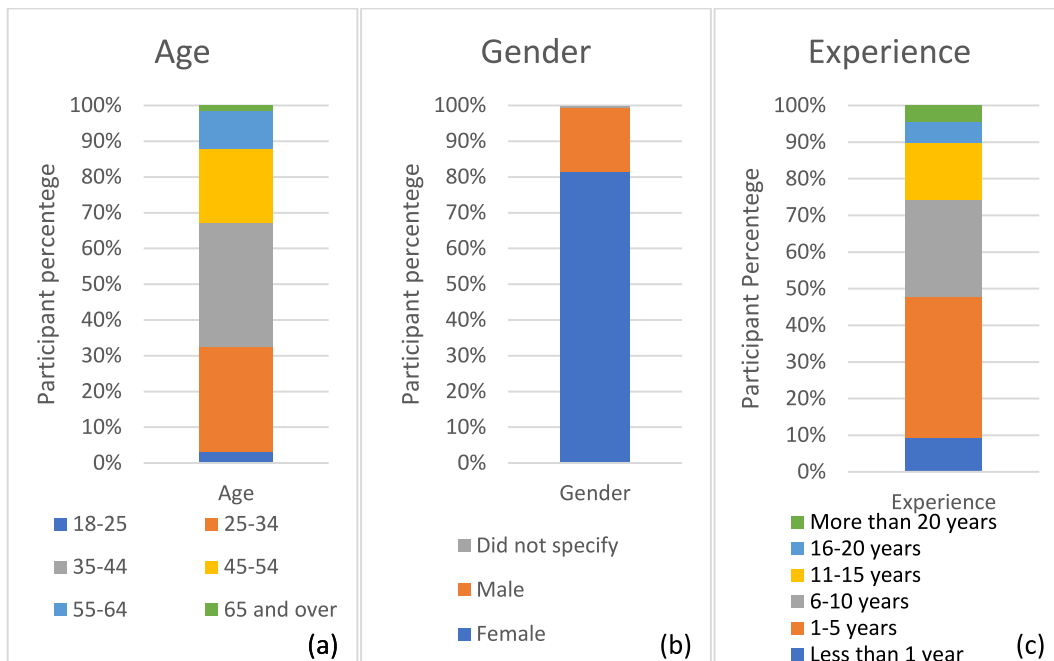


Fig. 1. Participant percentage of age (a), gender (b) and experience (c) distribution.

min outdoors in a day (Fig. 2).

3.1. Comfort-content and pleasantness-eventfulness combinations of school soundscape and associated factors

Overall, schools were perceived as annoying, eventful, chaotic, and vibrant, contradicting the monotonous and calm atmosphere expectation. It highlights the dynamic nature of learning institutions. While Fig. 3 shows the general sound perception of the schools, Fig. 4 shows the sounds of different places in the schools, on top of each other. The general framework is that schools are generally chaotic, vibrant and eventful places, but when researched in depth, it is observed that there are significant differences between school spaces.

In the school soundscape evaluation, two distinct questions were incorporated to explore their relationship with other parameters. One question focused on assessing acoustic comfort, while the other delved into perceptions of the school soundscape overall. By including both

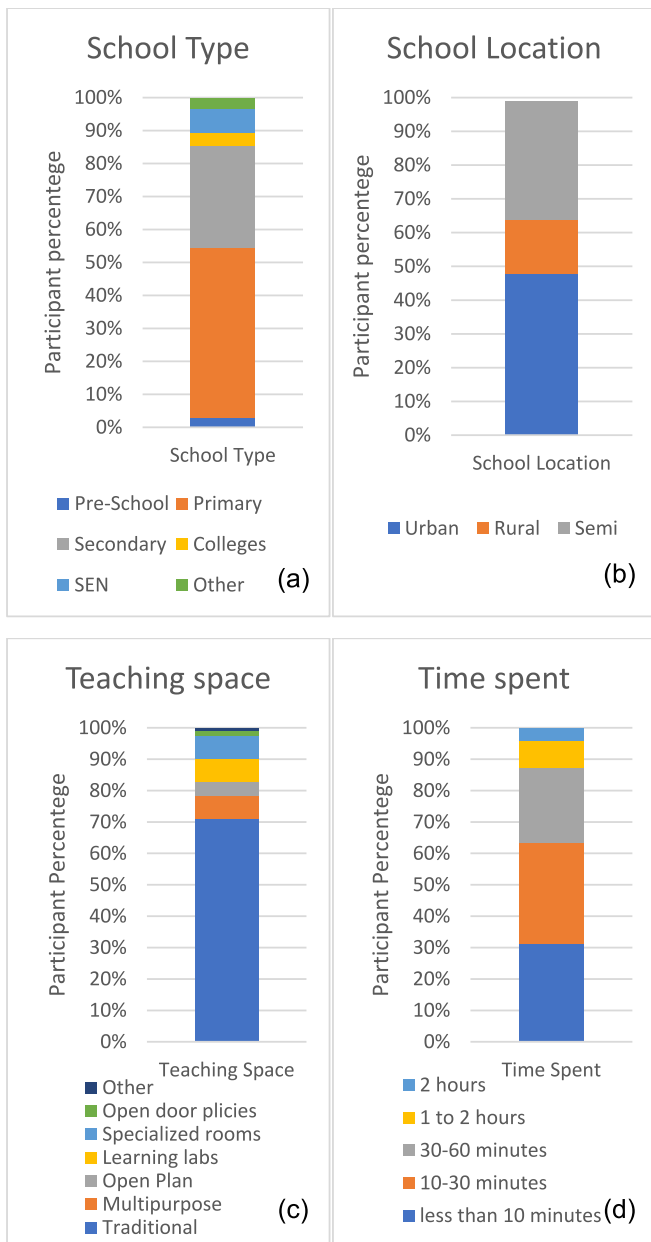


Fig. 2. Participant percentage of School Type (a), school location (b), Teaching space (c), Time spent distribution (d).

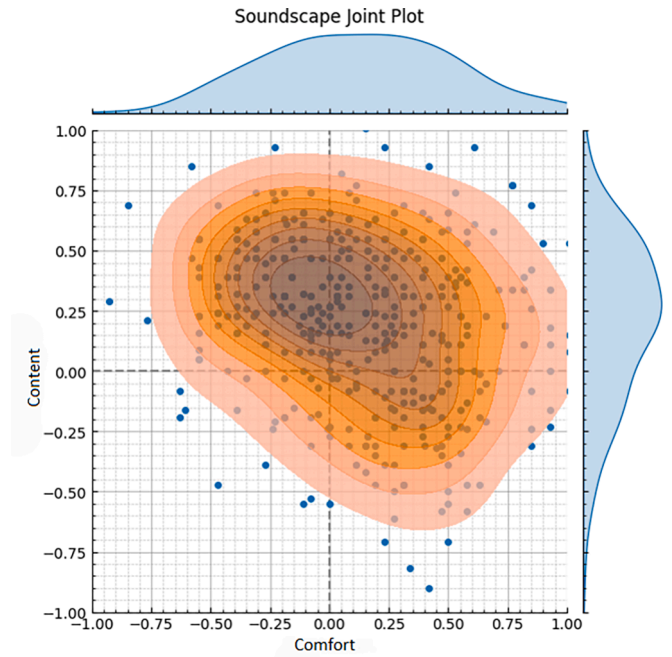


Fig. 3. The visualization of teachers' perceptions of the school soundscape across all types of spaces, whole dataset.

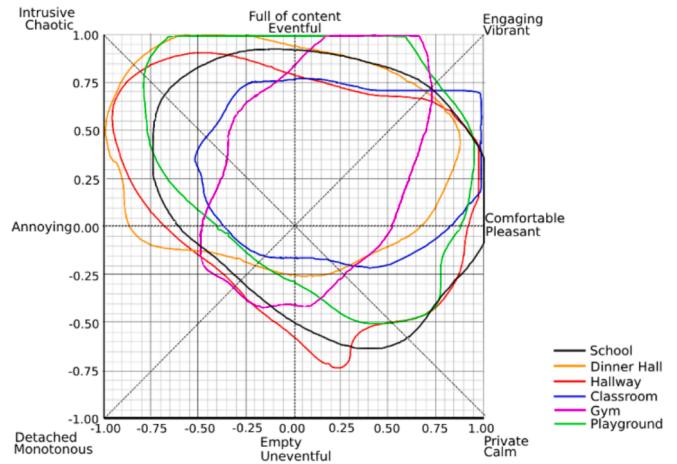


Fig. 4. Overlaying soundscapes from different areas within schools, whole dataset.

questions, the aim was to investigate whether there were disparities between perceptions of the school soundscape and perceptions of acoustic comfort. This allowed for an understanding of whether teachers were aware of any differences in their perceptions of these aspects.

3.1.1. Age

A correlation analysis was conducted between age and two questions: one regarding the acoustic comfort of the school and the other evaluating the soundscape of the school. The table presents correlations between age, perceptions of the acoustic environment, and overall perceptions of the school environment. There was a small, positive correlation between age and acoustic comfort, $r_s([450])=[.116]$, $p=[.013]$, indicating that as age increases, acoustic comfort ratings slightly increase. However, this relationship is relatively weak. The correlation between age and overall school soundscape was not statistically significant, $r_s([450])=[.082]$, $p=[.083]$, indicating no meaningful relationship between these variables.

3.1.2. Gender

Gender; The correlation between acoustic comfort and gender was not statistically significant, $r_s([450])=[.060]$, $p=[.202]$, suggesting no meaningful relationship between these variables. Similarly, the correlation between overall school soundscape and gender was not statistically significant, $r_s([450])=[.033]$, $p=[.486]$, indicating no substantial relationship between these variables.

3.1.3. Experience

Experience; A weak, positive correlation was found between acoustic comfort and years in current school, $r_s([450])=[.117]$, $p=[.013]$, indicating that individuals who have been in their current school longer tend to report slightly higher acoustic comfort. There was a weak, positive correlation between overall school soundscape and years in current school, $r_s([450])=[.124]$, $p=[.008]$, suggesting that individuals who have been in their current school longer tend to rate the overall school soundscape slightly higher.

3.1.4. School type

A weak, negative correlation was found between acoustic comfort and type of school, $r_s([450])=[-.109]$, $p=[.021]$, indicating that the type of school (pre-school, primary, secondary, colleges, SEN school, other) has a slight negative association with acoustic comfort ratings. There was a weak, negative correlation between overall school soundscape and type of school, $r_s([450])=[-.145]$, $p=[.002]$, suggesting that the type of school is slightly negatively associated with overall school soundscape ratings.

3.1.5. School location

A weak, positive correlation was found between acoustic comfort and place of school, $r_s([450])=[.098]$, $p=[.037]$, indicating that the place of the school (Urban to rural) The correlation between overall school soundscape and place of school was not statistically significant, $r_s([450])=[.056]$, $p=[.232]$, suggesting no substantial relationship between these variables.

3.1.6. Time spent in outdoor places

A weak, positive correlation was found between acoustic comfort and time spent outdoors, $r_s([450])=[.096]$, $p=[.041]$, indicating that more time spent outdoors is slightly associated with higher acoustic comfort ratings. A weak, positive correlation was observed between overall school soundscape and time spent outdoors, $r_s([450])=[.172]$, $p[<.001]$, suggesting that more time spent outdoors is slightly associated with higher overall school soundscape ratings.

3.1.7. Wellbeing

The TSWQ provides interpretation guidelines based on the average-item response. The questionnaire gived a composite score of 24.5. It may correspond to an average-item response falling between “often” and “almost always” on the response options. This suggests that, on average, teachers in this study report experiencing a relatively high level of wellbeing in their professional context.

Reflecting on the teaching efficacy and school connectedness scores:

Teaching Efficacy (12.7): This score indicates the average level of perceived effectiveness and confidence in teaching among the teachers in the study. This suggests that, on average, teachers perceive themselves as moderately effective in helping students learn new things and feel confident in their teaching abilities (often-always).

School Connectedness (11.8): This score reflects the average level of perceived connectedness and belongingness to the school environment among the teachers. This suggests that, on average, teachers feel moderately connected to the school community and environment (sometimes-often).

The table presents correlations between wellbeing, teaching efficacy, school connectedness, acoustic comfort, and overall school soundscape.

A moderate, positive correlation was found between acoustic

comfort and wellbeing, $r_s([450])=[.286]$, $p[<.001]$, indicating that higher acoustic comfort is associated with better wellbeing. The correlation between acoustic comfort and teaching efficacy was not statistically significant, $r_s([450])=[.029]$, $p=[.532]$, suggesting no meaningful relationship between these variables. The correlation between acoustic comfort and school connectedness was not statistically significant, $r_s([450])=[.055]$, $p=[.245]$, indicating no substantial relationship between these variables.

There was a moderate, positive correlation between overall school soundscape and wellbeing, $r_s([450])=[.372]$, $p[<.001]$, suggesting that a better overall school soundscape is associated with improved wellbeing. The correlation between overall school soundscape and teaching efficacy was not statistically significant, $r_s([450])=[-.009]$, $p=[.855]$, suggesting no meaningful relationship between these variables. The correlation between overall school soundscape and school connectedness was not statistically significant, $r_s([450])=[-.038]$, $p=[.418]$, indicating no substantial relationship between these variables (Table 2).

3.1.8. Teaching Places

“Good” ratings are predominant across most types of classrooms, suggesting that respondents generally perceive the school soundscape positively. “Very good” ratings are less common across all types of classrooms, indicating that very few respondents perceive the school soundscape as excellent. “Very bad” ratings are extremely rare, indicating that the majority of respondents did not perceive the school soundscape as significantly problematic. There is variation in ratings among different types of classrooms, suggesting that the physical layout and design of the classroom may influence respondents’ perceptions of the school soundscape. While Good ratings are common across most types of classrooms, there are variations in the distribution of ratings among different types. Some types, like Open Plan Classrooms and Other Classrooms, have higher percentages of Good ratings, while others, like Traditional Cellular Classrooms and Learning Labs, have lower percentages of Very good ratings. Additionally, Open Door Policy Classrooms stand out with a high percentage of Neutral ratings (Fig. 5).

The most common rating for Traditional Cellular Classroom was “Sometimes” (42.55 %), followed by “Often” (40.68 %). It has the highest percentage of respondents who rated the acoustic comfort as “Sometimes” compared to other types of classrooms. It has a relatively low percentage of respondents who rated the acoustic comfort as “Rarely” (7.45 %). Multipurpose Space has a fairly even distribution of ratings across “Rarely,” “Sometimes,” and “Often” categories. It has the highest percentage of respondents who rated the acoustic comfort as “Often” (31.25 %) compared to other types of classrooms. It has the lowest percentage of respondents who rated the acoustic comfort as “Never” (0.00 %). Open Plan Classrooms were similar to the multipurpose space, this type of classroom also has a fairly even distribution of ratings across “Sometimes” and “Often” categories. It has the highest percentage of respondents who rated the acoustic comfort as

Table 2

Spearman’s Correlations between Different factors in school and Acoustic comfort and soundscape evaluation of Teachers.

	Acoustic comfort evaluation	School soundscape evaluation
Age	0.116*	0.082
Gender	0.060	0.033
Experience	0.117*	0.124**
School Type	−0.109*	−0.145**
School Location	0.098*	0.056
Time spent in outdoor places	0.096*	0.172**
Wellbeing	0.286**	0.372**
Teaching efficacy	0.029	−0.009
School connectedness	0.055	−0.038

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

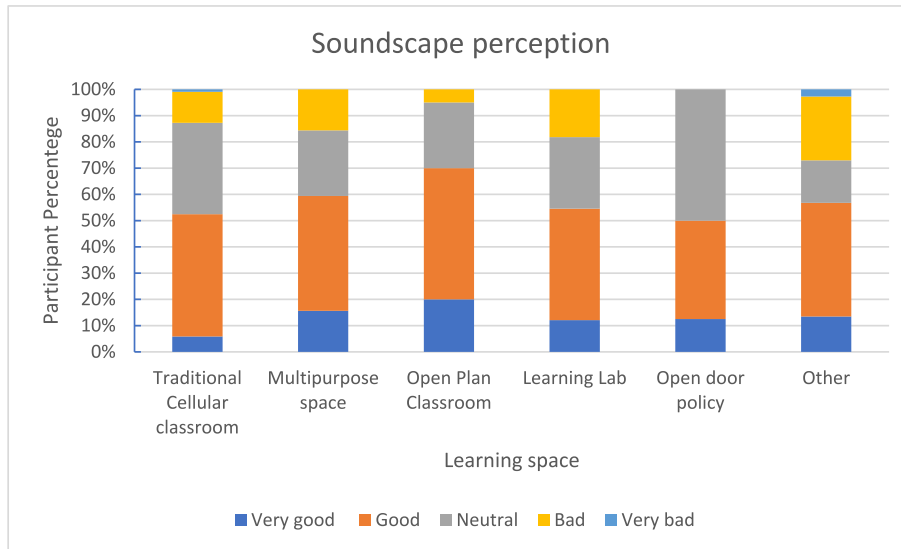


Fig. 5. Teachers' Soundscape Experiences Across Teaching Environments.

“Sometimes” (30.00 %) compared to other types of classrooms. It has a relatively low percentage of respondents who rated the acoustic comfort as “Never” (0.00 %). Learning Lab or Specialized Rooms has the highest percentage of respondents who rated the acoustic comfort as “Sometimes” (42.42 %). It has a relatively low percentage of respondents who rated the acoustic comfort as “Never” (6.06 %). Open Door Policy was similar to other types, has a fairly even distribution of ratings across “Sometimes” and “Often” categories. It has the highest percentage of respondents who rated the acoustic comfort as “Often” (37.50 %) compared to other types of classrooms. It has the lowest percentage of respondents who rated the acoustic comfort as “Never” (0.00 %) (Fig. 6).

Overall, there is variation in the distribution of acoustic comfort ratings among different types of classrooms, with some types having higher percentages of certain ratings compared to others. Additionally, some types have more even distributions of ratings across categories, while others show more distinct patterns.

3.1.9. Sounds

Understanding the prevalence of different auditory experiences in

the school environment can inform strategies for creating conducive learning environments. Fig. 7 displays the percentage of teachers reporting various auditory experiences within the school environment. Birds singing, traffic, and bells are reported across a wide range of frequencies, indicating variability in their occurrence within the school environment. Some sounds, like screaming and playing children, are reported more frequently by teachers, which could have implications for classroom management and student behaviour. Rare occurrences of certain sounds, such as trains and airplanes, may suggest that the school is located in an area less impacted by these environmental factors. Addressing disruptive sounds (e.g., screaming) may be a priority for improving the classroom atmosphere and student concentration.

Awareness of environmental sounds like construction or sirens can help in scheduling activities or adapting teaching methods to minimize disruptions.

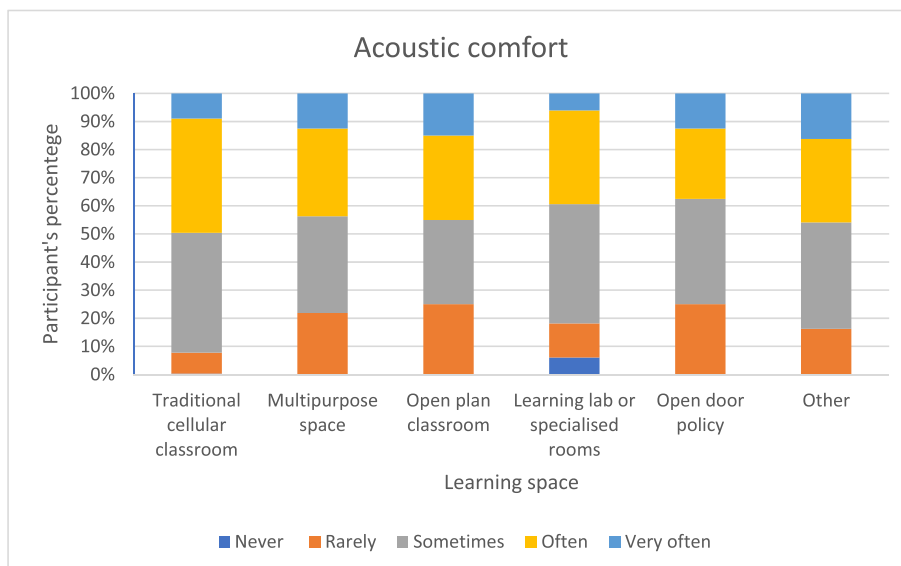


Fig. 6. Teachers' acoustic comfort evaluation for different teaching spaces.

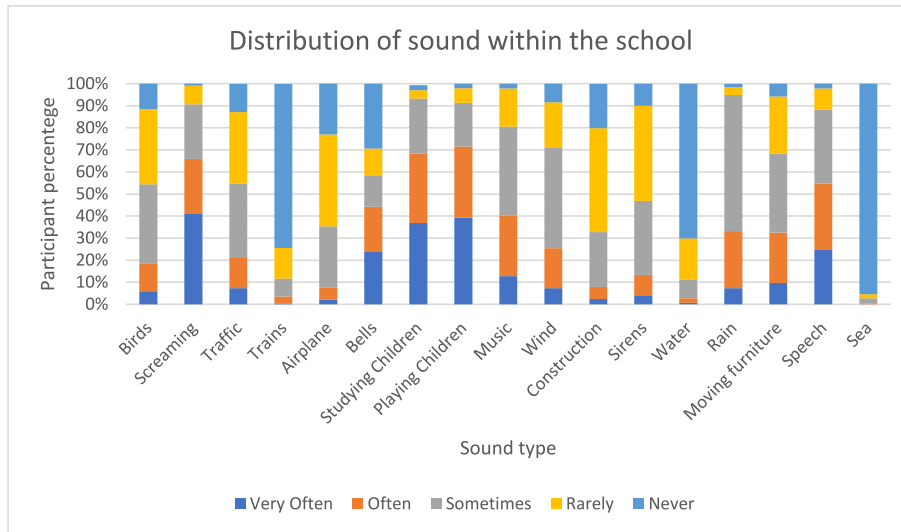


Fig. 7. Teacher-Perceived Distribution of Ambient Sounds in School Environments.

3.2. Comfort-content and pleasantness-eventfulness combinations of different spaces in school

In this section, school places' soundscapes (the dinner hall, gym, hallways, playground, and classrooms) have been evaluated respectively. This figure illustrates a comparison between the soundscapes of school places and school soundscape (Fig. 8).

Playgrounds (outdoor); Although comparing indoor and outdoor environments in terms of soundscape can pose challenges due to their inherent differences, examining the soundscape of playgrounds compared to that of school interiors provides insights into their

respective representations. Additionally, exploring how the indoor and outdoor areas of the school differ and impact the daily experiences of teachers is crucial. Therefore, this study focuses on understanding the distinctions between these spaces beyond their indoor-outdoor dichotomy. Since playgrounds were the only outdoor spaces considered in this study, comparing them solely with indoor environments posed a unique challenge. Despite the playgrounds sharing similarities with the school soundscape, the latter appears to be richer in content, more engaging, and potentially more chaotic due to its intrusiveness. Another crucial observation regarding playgrounds is their similarity to the soundscape within the school soundscape, when we compare with

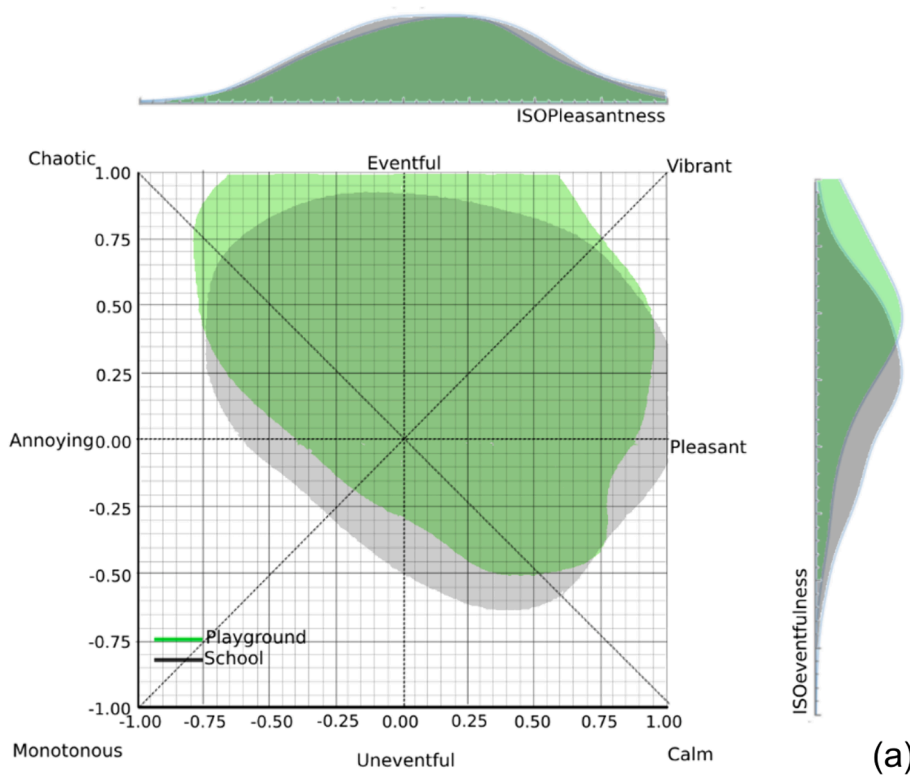


Fig. 8. The comparison of the school places' soundscape with schools' soundscape. On the top left (a) School soundscape and playground soundscape comparison, on the top right (b) School soundscape and dinner hall soundscape comparison, on the middle left (c) School soundscape and gym soundscape comparison, on the middle right (d) School soundscape and hallway soundscape comparison, on the bottom left (e) school soundscape and classroom soundscape comparison has been shown.

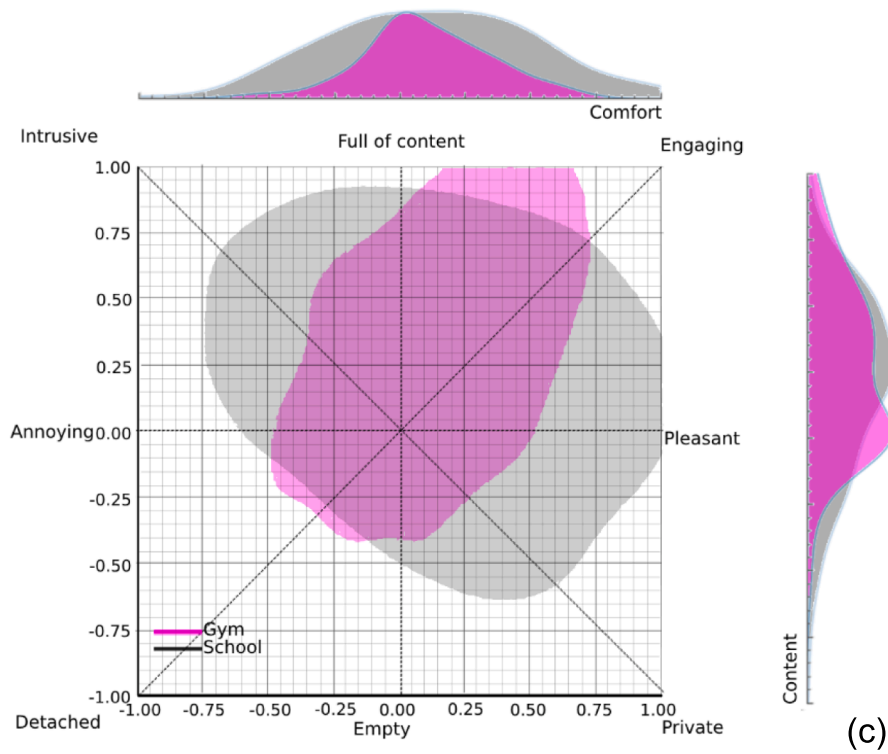
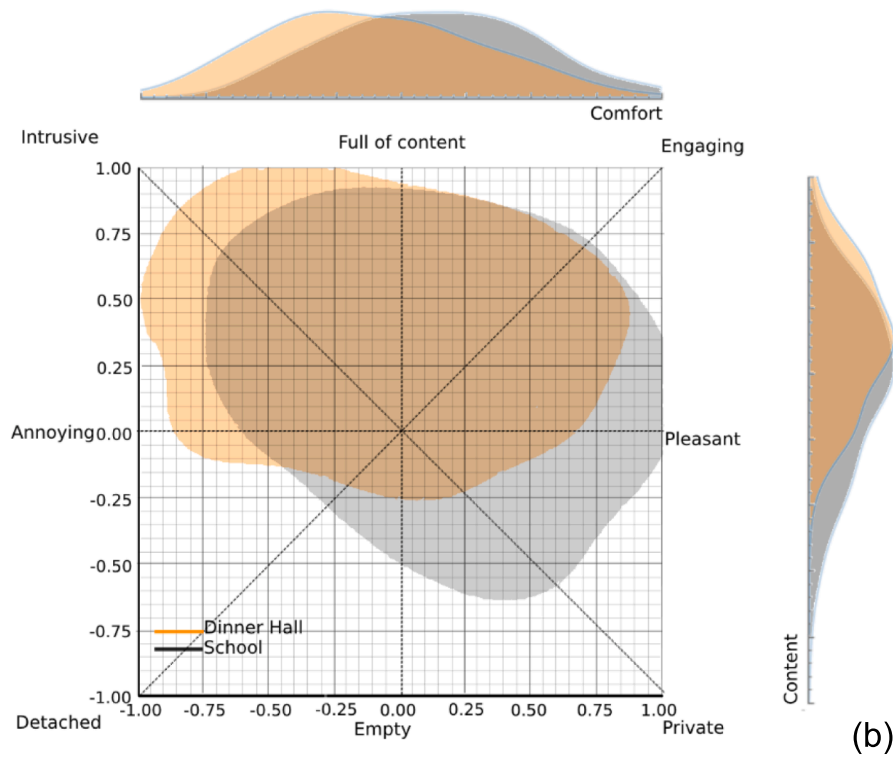


Fig. 8. (continued).

classrooms, gyms, and dining halls. This suggests that the function of a space significantly influences sound perception, sometimes even more so than whether the space is indoors or outdoors.

Dinner halls emerged as notably more intrusive and less private spaces compared to the school soundscape. They are characterized by a richness of activity similar to the general school atmosphere yet offer

less comfort and can be mildly annoying.

Gyms, *Gyms* prove to be notably more immersive environments when compared to the overall soundscape of the school. They exhibit a narrower range on the circumplex, indicating a heightened sense of engagement among participants. While slightly less comfortable than the school environment, they also tend to be less annoying. The

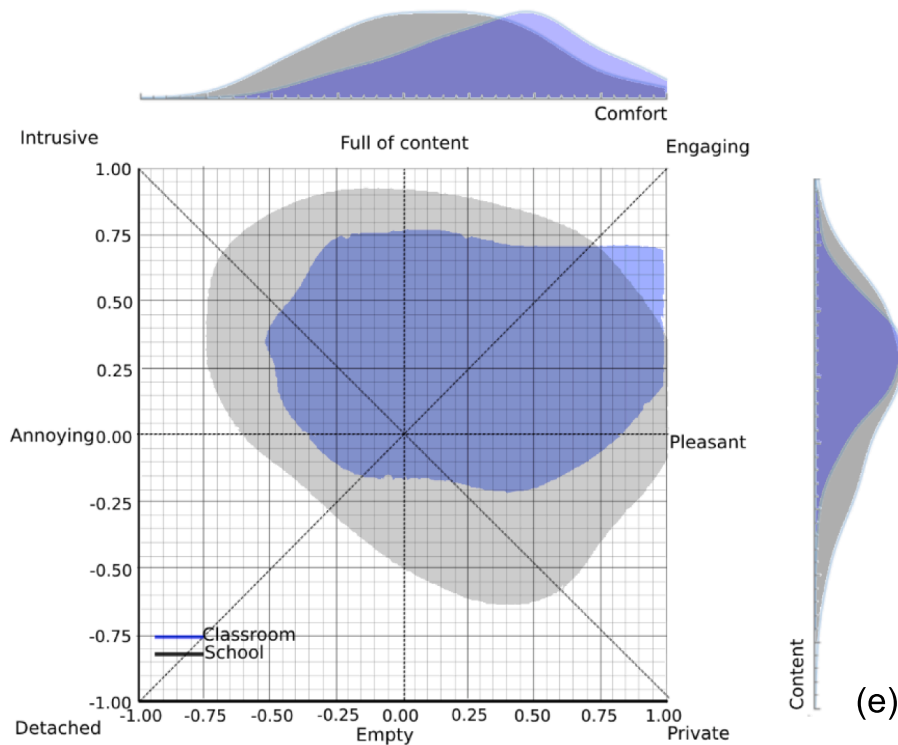
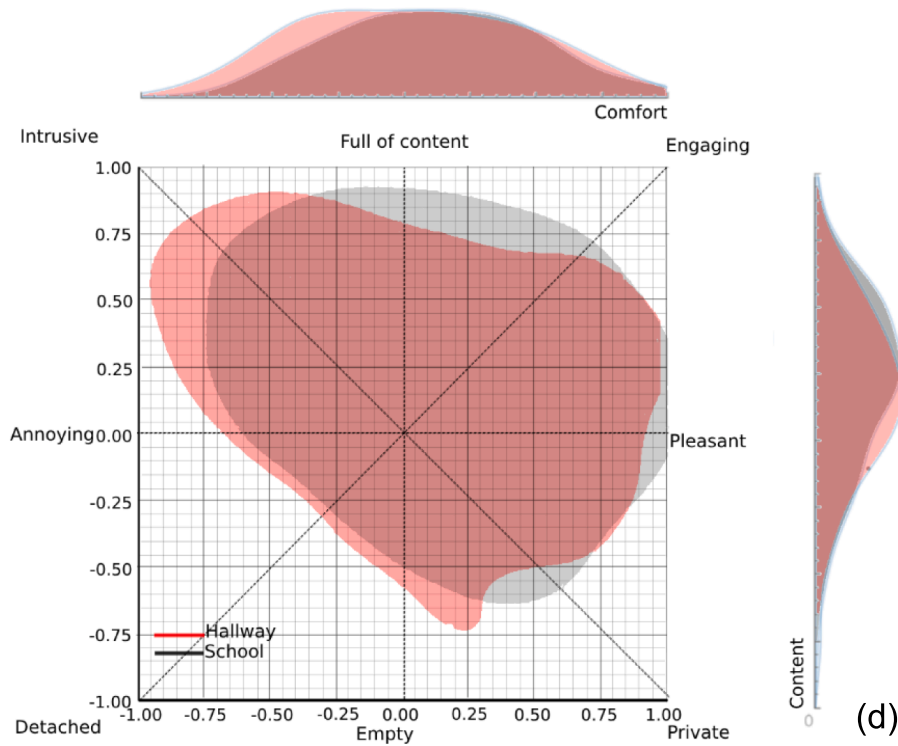


Fig. 8. (continued).

emphasis on engagement emerges as a key characteristic defining gyms.

Hallways, Hallways emerge as pivotal components of the school soundscape due to their closeness to the school sound environment. They closely mirror the overall school soundscape but are characterized by a heightened level of intrusiveness and reduced privacy.

Classrooms, exhibit a more defined and concentrated soundscape

compared to the broader school environment. They offer a heightened level of engagement and comfort, surpassing that of the school as a whole. However, intriguingly, they appear to offer less privacy despite their focused nature.

In summary, these observations highlight the complex dynamics at play within school environments and emphasize the multifaceted

nature of sound perception of school, influenced not only by physical attributes but also by the function and activities of each space.

3.3. Qualitative analysis

Specifically, 62 teachers reported always using music and sounds to enhance the learning environment, while 103 teachers indicated that they generally integrate sound, as part of a broader teaching paradigm. Additionally, 157 teachers reported using sound sometimes, 49 teachers rarely utilized sound, and 90 teachers stated that they never used sound. These findings suggest that sound plays a significant role in the school environment.

Thematic analysis has been conducted to analyse the results of open-ended questions. Codes were organized into thematic categories representing patterns within the data. Three main themes emerged: “Why,” “How,” and “Outcomes.” The “Why” theme encompassed codes related to the reasons behind the use of sound in educational settings. The “How” theme comprised codes detailing the methods and strategies employed by teachers to integrate sound into their teaching practices. Finally, the “Outcomes” theme included codes describing the perceived impacts of sound on student wellbeing and learning outcomes. Under the ‘how’ theme, codes were identified such as using students’ preferences, employing sound as an educational tool, integrating sound during independent work, and incorporating sound as a routine for specific

activities. Within the ‘why’ theme, codes included creating a calm atmosphere, connecting with nature, facilitating topic teaching, transitioning between activities, engaging students, making lessons interesting, and signifying the end and beginning of lessons. Finally, under the ‘outcomes’ theme, codes encompassed relaxation, sensory experiences, concentration, and creativity. It’s important to note that all these codes and themes were directly related to student learning or wellbeing. Additionally, many of these themes and codes exhibited interrelationships, with some serving as both reasons for and results of each other (Fig. 9).

Within the thematic analysis, both direct and indirect relationships between codes were identified. Direct relationships involved codes that appeared in the same sentence, indicating a direct association between concepts. Indirect relationships were identified through the analysis of teachers’ comments, where a reason and result relation were implied.

4. Discussion

This discussion will explore the implications of the research gap identified in the study of soundscapes in educational settings, emphasising the need for a comprehensive exploration of sound elements in schools.

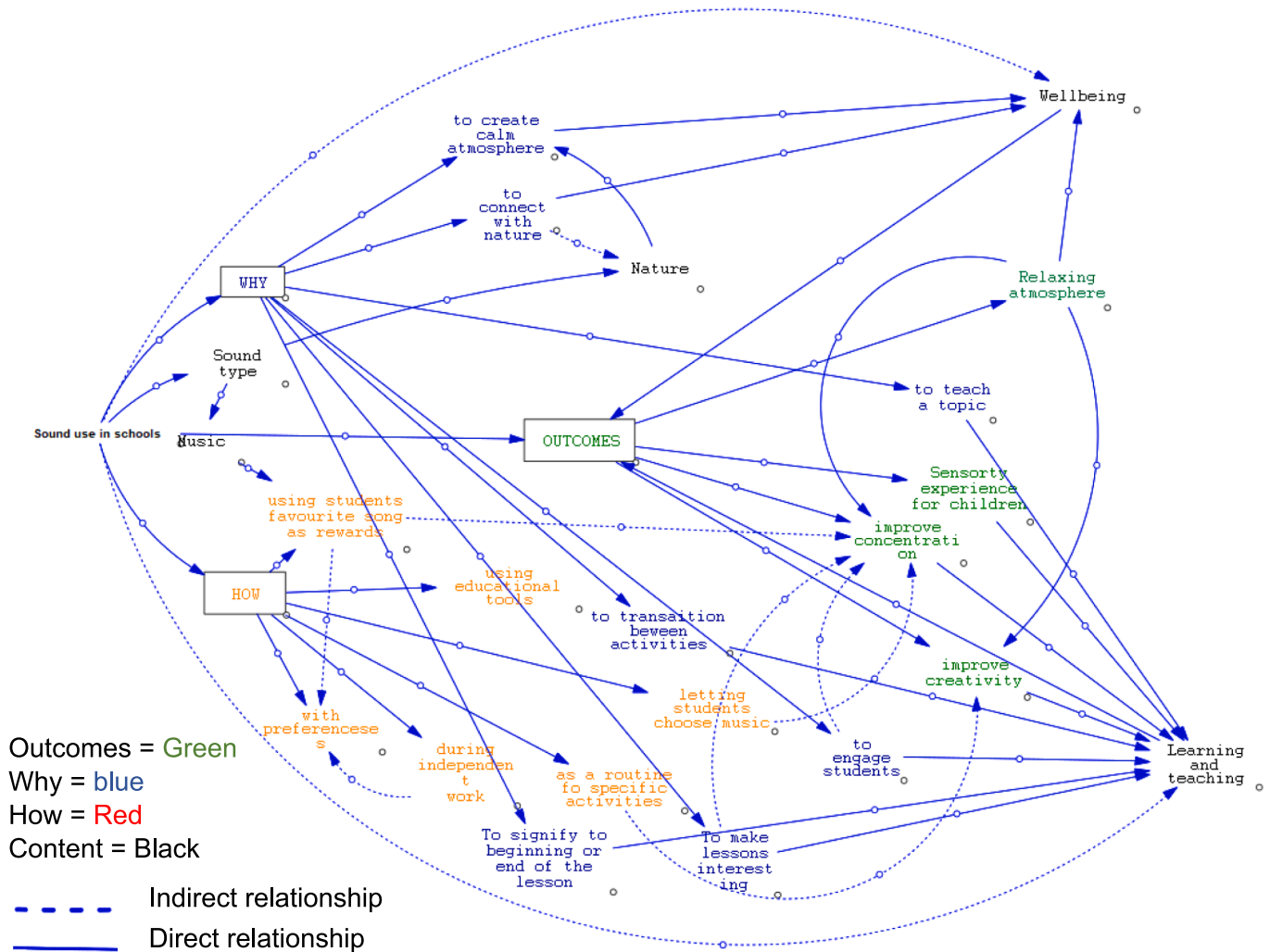


Fig. 9. Sound Use Relationships in School (Outcomes (green), Why sound is used (blue), How sound is used (red), and Content related to sound (black)). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.1. School soundscape

While classroom acoustics and noise protection have been a primary focus in school acoustic literature, the overall soundscape of the school is a multifaceted entity. To create truly conducive learning environments, it is crucial to extend research efforts beyond individual classrooms and address the diverse auditory needs (needs of positive sounds) of various spaces within educational institutions. Findings indicate that teachers perceive the school soundscape as eventful, chaotic, and vibrant. However, it's noteworthy that some teachers also perceive it as calm, suggesting that the school environment is not uniformly problematic. Nevertheless, when considering the broader context of the school, it becomes crucial for researchers to delve deeper into understanding when and under what sound environments this sense of calmness occurs within schools.

These findings prompt us to question whether solely addressing noise reduction in schools is sufficient, or if we should also consider sound as a resource in certain cases within the school environment. Furthermore, it's worth noting that the conventional approach to school acoustics predominantly emphasizes the educational function of schools and prioritizes quieter environments. However, schools are multifaceted social spaces, and various functions within them are also significant. Therefore, the literature on school acoustics should adopt a holistic perspective, recognizing and addressing the diverse experiences and needs of different areas within the school environment, rather than underestimating the importance of non-educational spaces.

Findings also illustrated the diversity of individual perceptions within schools. Factors such as age, experience, specific school locations, and the nature of experiences influence how teachers perceive the soundscape around them. Therefore, it's crucial to consider these relationships when studying solutions for school acoustics. These findings suggest that each school's soundscape is unique and may require tailored remedies to enhance wellbeing. While the results showed only moderate improvements in teacher wellbeing, we identified a significant positive correlation between the perception of the school soundscape and wellbeing. Thus, addressing acoustic conditions in schools could be a valuable avenue for improving overall wellbeing.

4.2. Soundscape in different places in school

The consideration of acoustic research in various settings beyond classrooms is essential due to the diverse impact of soundscapes on different environments. The acoustics of school environments, including dinner halls, gyms, hallways, and playgrounds, play a crucial role in influencing various aspects of the school environment. Research has shown that poor room acoustics in schools can lead to difficulties in speech intelligibility, increased noise levels, and reduced comfort, affecting the overall experience of students and teachers [35,5]. Studies often focus solely on reducing sounds in these environments. However, this study revealed that some spaces exhibit pleasantness and calmness. This suggests that certain types of sounds could be beneficial for these environments. Furthermore, we found that each space has its unique soundscape, despite all of them demonstrating a level of eventfulness in sound. The degree of chaos and calmness varies between these spaces. Therefore, it is crucial to consider these perceptions of the soundscape to enhance the overall school sound experience.

The holistic approach will contribute to a more nuanced understanding of the school's sound environment and enable the development of interventions that provide to the unique acoustic requirements of each space, ultimately enhancing the overall educational experience.

4.3. The Role of Sound in School

The use of sound by teachers in schools is a multifaceted aspect that encompasses various dimensions. Teachers utilize sound to create an engaging and effective learning environment, as well as to ensure safety

and wellbeing within the school setting. The use of sound by teachers is influenced by their knowledge, attitudes, and practices, and it plays a crucial role in shaping the overall educational experience.

Research has shown that teachers' perceptions and practices regarding sound in the classroom are essential for creating a conducive learning environment Manjunath & Kumar (2013). Understanding teachers' knowledge, attitudes, and practices regarding sound can provide insights into how they utilize sound to support learning and student engagement.

The use of sound by teachers is also crucial for ensuring safety and wellbeing within the school environment. Teachers' understanding of the acoustics of different school spaces, such as gymnasiums, hallways, and playgrounds, is essential for creating safe and healthy sound environments for students. Teachers who have experience how to use sound effectively can support communication by minimizing unwanted sounds. This can help maintain safety during activities and transitions. Additionally, in this study, the data drawn from qualitative analyses imply teachers' awareness of the impact of sound on student wellbeing and learning can influence their practices in managing sound in various school settings.

In this study, it was found that the majority of teachers actively employed sounds and incorporated them into various aspects of the school environment, including classrooms. They utilized sounds as educational tools, rewards for children, and means to relax them. Additionally, sound proved to be an effective stimulus tool for special needs children when used appropriately. Furthermore, sound has served as a longstanding reminder of times within the school day, such as beginning and end times. However, it's essential to note that the selection of these sounds is crucial for enhancing wellbeing in schools. Teachers who incorporated sounds reported several positive outcomes, including an improved learning environment and enhanced wellbeing. Understanding how teachers utilize sound to create engaging learning environments, ensure safety and wellbeing, and support student learning is essential for promoting effective teaching practices and enhancing the overall educational experience.

4.4. Limitations

The study, while comprehensive, has several limitations. Despite a sample size of 452, which is relatively large and diverse, it may not fully represent the entire population of UK teachers. Self-selection bias is a concern, as those who chose to participate might differ systematically from those who did not, potentially skewing the results. Additionally, response bias may occur if participants provide socially desirable answers or fail to accurately recall their experiences. The exclusion of incomplete or quick engagement responses, although aimed at ensuring data integrity, might have inadvertently introduced bias. Despite these limitations, the study provides valuable insights, and future research could address these constraints to enhance understanding in this area.

Moreover, our study is not generalizable to teachers in other countries due to contextual differences in educational systems, cultural norms, and school environments. However, the findings may be transferable to similar contexts where comparable conditions and practices exist.

5. Conclusions

An online questionnaire was administered to 452 UK teachers, and both qualitative and quantitative analyses were conducted. The conclusions drawn correspond to the research question posed in the study.

- The school soundscape, characterized by a mix of chaos, eventfulness and engagement. It's noteworthy that some teachers also perceive it as calm (private or controlled), suggesting that the school environment is not uniformly problematic. Nevertheless, when considering the broader context of the school, it becomes crucial for researchers

to delve deeper into understanding when and under what sound environments this sense of calmness occurs within schools. Our findings also illustrated the diversity of individual perceptions within schools. Factors such as age, experience, specific school locations, and the nature of experiences influence how teachers perceive the soundscape around them.

- Nuanced differences in soundscapes across various school spaces were revealed. It was found that each space has its own unique soundscape, despite all of them demonstrating a level of eventfulness in sound. The findings emphasize the importance of considering the diverse auditory needs of classrooms, hallways, dinner halls, outdoor areas, and other spaces within educational institutions to enhance overall school experience.
- The majority of teachers actively employed sounds and incorporated them into various aspects of the school environment, including classrooms. Teachers who incorporated sounds reported several positive outcomes, including an improved learning environment and enhanced wellbeing.

Understanding and addressing the school soundscape experience as a whole is crucial for designing learning environments that accommodate the diverse auditory needs of students and educators. This study offers insights into enhancing the educational experience through a nuanced understanding of school soundscapes.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full

responsibility for the content of the publication.

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CRedit authorship contribution statement

Hatice Kurukose Cal: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Francesco Aletta:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Jian Kang:** Supervision, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

APPENDIX. Questionnaire excerpt

BACKGROUND.

Question	Scale	Label
How old are you?		18 to 24; 25 to 34; 35 to 44; 45 to 54; 55 to 64; 65 or over
How long have you been working in the current school?		Less than 1 year; 1–5 years; 6–10 years; 11–15 years; 16–20 years; more than 20 years
Gender		Free text
How many hours on average do you spend in school per day?		2–4 h; 4–6 h; 6–8 h; more than 8 h
What is the type of your school?		Pre-school; Primary school; Secondary school; Colleges; SEN school; Other
How would you describe your school’s location?		Urban; Rural; Semi-urban
What kind of space do you primarily teach in?		Traditional cellular classroom; Multipurpose space; Open plan classroom (a school built to a design which does not include self-contained classrooms); Learning lab or specialised rooms; You have open-door policy (classroom doors need to be open during lessons); Gym; Other
In your current school, do you have outdoor space(s) Yes (Gardens, playground, courtyards)? If yes, how long do you normally spend in such outdoor space(s) per day?		Less than 10 min; 10–30 min; 30–60 min; 1–2 h; More than 2 h

SOUNDS

Question	Scale	Label
When you think about your day in school, how often do you hear the sounds (birds singing, screaming, and shouting, Traffic, Trains Airplanes, School bells, children reading and/or studying, children singing, music, the breeze of wind, construction sound, ambulance or police sirens, water fountain, rain, moving furniture sound, people speech, sea sounds, below?	Likert	Very often; Often; Sometimes; Rarely; Never
Have you ever used sounds while you were teaching for a better learning environment? (Such as some piece of music)	Likert	Always; Generally; Sometimes; Rarely; Never
If yes, could you please explain in a couple of sentences?		
Have you ever used sounds while you were teaching to support children’s wellbeing? (Such as some piece of music)	Likert	Always; Generally; Sometimes; Rarely; Never
If yes, could you please explain in a couple of sentences?		
Overall, when you are in your school, how often do you find the acoustic environment to be comfortable?	Likert	Always; Generally; Sometimes; Rarely; Never

WELLBEING ITEMS

Question	Options
1. I feel like I belong at this school.	Almost Never; Sometimes; Often; Almost Always
2. I am a successful teacher.	Almost Never; Sometimes; Often; Almost Always
3. I can really be myself at this school.	Almost Never; Sometimes; Often; Almost Always
4. I am good at helping students learn new things.	Almost Never; Sometimes; Often; Almost Always
5. I feel like people at this school care about me.	Almost Never; Sometimes; Often; Almost Always
6. I have accomplished a lot as a teacher.	Almost Never; Sometimes; Often; Almost Always
7. I am treated with respect at this school.	Almost Never; Sometimes; Often; Almost Always
8. I feel like my teaching is effective and helpful.	Almost Never; Sometimes; Often; Almost Always

SOUNDSCAPE

QUESTIONS

OPTIONS

	Indoors	Outdoors
	Strongly agree; Agree; Neutral; Disagree; Strongly disagree.	
For each of the 8 scales below, to what extent do you agree or disagree that the sound environment of your SCHOOL/ CLASSROOM/ PLAYGROUNDS or OUTDOOR SPACES/ HALLWAYS/ DINNER HALLS and CANTEEN/ SCHOOL GYM is...	ANNOYING; UNEVENTFUL; CHAOTIC; MONOTONOUS; PLEASANT; EVENTFUL; CALM; VIBRANT	ANNOYING; EMPTY; INTRUSIVE; DETACHED; COMFORTABLE; FULL OF CONTENT; PRIVATE; ENGAGING
Overall, how would you describe the sound environment of SCHOOL/ CLASSROOM/ PLAYGROUNDS or OUTDOOR SPACES/ HALLWAYS/ DINNER HALLS and CANTEEN/ SCHOOL GYM is...	Very good; Good; Neutral; Bad; Very bad	

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