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Review Article

The Effects of Classroom Acoustic Conditions on Teachers' Health and Well-Being: A Scoping Review

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ABSTRACT

Purpose: Teachers spend a significant amount of time in classrooms, which can be noisy environments. The aim of this scoping review was to determine what is known from the literature about the effect of classroom acoustic conditions on teachers' health and well-being.
Method: This scoping review followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) protocol. Four bibliographic databases were searched: ERIC, PubMed, Scopus, and Web of Science.
Results: Thirty-three articles were deemed relevant for the review. The most studied health aspect was teachers' vocal health. The majority of results showed higher noise levels or a higher number of students have a negative effect on teachers' health and well-being (61% and 60%, respectively), while 39% showed a negative effect of longer reverberation times. Most other results showed no effect.
Conclusions: These results show that poor classroom acoustic conditions can have a negative effect on teachers' health and well-being. Therefore, creating classrooms with good acoustic conditions and controlling noise is vital. Limitations are discussed, and future research to better understand the relationship between classroom acoustic conditions and teachers' health and well-being is proposed. This future research will help in understanding the acoustic conditions that are needed to optimize teachers' health and well-being in the classroom.

Teachers spend a significant amount of time working in classrooms. At the preprimary level, teachers spend 1,001 hr per year teaching; at the primary school level, they spend 782 hr teaching; at the lower secondary school level, they spend 694 hr teaching; and at the upper secondary school level, they spend 655 hr teaching (OECD, 2014). Classrooms can be noisy environments (American Speech-Language-Hearing Association, 2005; Mealings, 2016). Therefore, it is important to consider how the acoustic environment affects teachers' health and well-being.

Classroom Noise and Acoustics

There are many different noise sources heard in the classroom. External environmental noise may be present such as traffic, railway, and aircraft noise (Mealings, 2021; Shield & Dockrell, 2004). Additionally, there are internal noises such as talking and from movement of the children (Mealings, 2021; Shield & Dockrell, 2004). Occupied classroom noise levels have been shown to range from 48 to 85 dBA (Mealings, 2016).

The effects of noise can be further exacerbated by reverberation (Crandell & Smaldino, 2000). Reverberation refers to the prolongation of a sound in a space. Reverberation is measured by the reverberation time of the room, which is the time it takes for a sound to decay by 60 dB (Schomer & Swenson, 2002). Longer reverberation times mean that the sound is more prolonged in the room.

Additional acoustic parameters that are also important to consider are early decay time (EDT), speech clarity (C50), definition (D50), signal-to-noise ratio (SNR), useful-to-detrimental ratio (U50), sound strength (G), attenuation (dL), and speech transmission index (STI).

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EDT is the time it takes for sound to decrease by 10 dB. C50 is the ratio of the early sound energy (between 0 and 50 ms) and the late sound energy (that arrives later than 50 ms). D50 is the ratio between the sound energy between 0 and 50 ms and the total energy. SNR is the ratio between the target signal and the background noise. U50 is obtained from D50 and SNR. G is the ratio of the sound energy of the measured impulse response to the response measured in free field 10 m from the sound source. dL is the reduction of sound strength. STI is a measure of the transmission of speech in a space. All of these parameters are useful in determining the suitability of the classroom as a teaching space.

Classroom Acoustic Recommendations

There are acoustic recommendations for classrooms, largely based on what is needed for accurate speech perception (i.e., the unoccupied noise level should be kept below 35–45 dBA (American National Standards Institute, 2010; Australia/New Zealand Standard, 2016), the occupied noise level should be below 50 dBA (Mealings, 2016), and the reverberation time should be 0.4–0.7 s (American National Standards Institute, 2010; Australia/New Zealand Standard, 2016; Crandell & Smaldino, 2000; Mealings, 2016; Minelli et al., 2022). There have also been research recommendations to support the propagation of early reflections and the teacher's speech in order to reduce vocal effort and enhance vocal comfort. These recommendations for classrooms with less than 40 students and volumes below 210 m^3 are for reverberation times in occupied classrooms to be 0.45–0.6 s (between 0.6 and 0.7 s in unoccupied but furnished conditions; Pelegrín-García et al., 2014).

However, these conditions are often not achieved (Mealings, 2016). Classrooms are often built near busy roads, railway lines, or under flight paths and are not acoustically treated. Group work activities, which can make up around 50% of teaching time (Imms et al., 2017; Mealings, Demuth, et al., 2015), also produce higher noise levels compared to whole class teaching or independent work (Mealings, Buchholz, et al., 2015; Shield & Dockrell, 2004). Additionally, more open-plan innovative learning environments are becoming popular (Imms et al., 2017), which have higher intrusive noise levels entering the class area from the other classes sharing the same space (Mealings, Buchholz, et al., 2015). Therefore, teachers are often teaching in suboptimal acoustic environments, which could affect their health and well-being.

Teachers' Health and Well-Being

Teachers' health and well-being has been a growing area of interest in recent years both in society and in research (Hascher & Waber, 2021). Interestingly, however, defining exactly what well-being encompasses has been a challenge for researchers (see Dodge et al., 2012, for a review). Dodge et al. (2012) have developed a definition of well-being as the following: "stable well-being is when individuals have the psychological, social and physical resources they need to meet a particular psychological, social, and/or physical challenge" (p. 230). Here, there are three main facets of well-being: psychological, social, and physical. For the purpose of this scoping review, the term "health and well-being" will be used to cover psychological, social, and physical well-being. Regarding psychological well-being, teachers are at increased risk of developing mental health disorders compared to people in other professions (Stansfeld et al., 2011). Regarding social well-being, social relationships play an important role for teacher well-being (Hascher & Waber, 2021). Regarding physical well-being, teachers are particularly susceptible to vocal fatigue (Moreno et al., 2022) and developing vocal health disorders (Nusseck et al., 2020). This is problematic not only for the teacher's health and well-being but also for the children, as they have more trouble perceiving and processing speech and recalling information when listening to a speaker with dysphonia (Schiller et al., 2022).

Impact of Noise and the Physical Environment on People's Health and Well-Being

The impact of noise on human health has been of growing concern. Noise can cause temporary or permanent hearing loss, sleep disturbance, fatigue, and increases in blood pressure, heart rate, and vasoconstriction (Berglund & Lindvall, 1995). The potential for these adverse health effects have led to the World Health Organization (WHO) Regional Office for Europe to devise guidelines for environmental exposure based on systematic reviews (WHO, 2018). The recommendations are based on minimizing negative effects on health and sleep (WHO, 2018). It is strongly recommended that the day-evening-night–weighted sound pressure level should be below 53, 54, 45, and 45 dB L_{den} for road traffic, railway, aircraft, and wind turbine noise, respectively. Safe Work Australia (2020) states that the national standard for maximum occupational exposure to noise is an average daily exposure level of $L_{Aeq,8hr}$ = 85 dB, as above this level poses a risk to the person's hearing. The national standard for peak exposure is L_{Cpeak} = 140 dB. Therefore, it is important that these recommended limits are achieved to help prevent the negative effects of noise on people's health.

The importance of the physical environment and people's well-being has also recently been growing attention in the academic literature as shown by the research topic on "Acoustics in the Built Environment: A Challenge for Improving the Quality of Life" published in the journal *Frontiers in Built Environment* (Astolfi et al.,

2022). In addition to the effects on physical health, these studies show that poor acoustic environments can also affect people's comfort, performance, and quality of life (Astolfi et al., 2022).

Aim of the Scoping Review

It has been established that high noise levels from environmental noise or at work can have an adverse effect on people's health and well-being. However, what about noise in the classroom environment? Recent reviews have shown that poor classroom acoustic conditions can negatively affect children's speech perception (Murgia et al., 2022), listening comprehension (Mealings, 2022a; Schiller et al., 2022), literacy (Mealings, 2022f), numeracy (Mealings, 2022a), cognition (Mealings, 2022e), behavior (Mealings, 2022d), physical health (Mealings, 2022c), and mental well-being (Mealings, 2022b). But what about the effect on teachers? Teachers have the added issue of being professional voice users, and the presence of noise and reverberation alters voice production by changing people's vocal comfort and vocal control (Sierra-Polanco et al., 2021).

Therefore, a scoping review process was conducted as outlined by Munn et al. (2018) "to identify the types of available evidence in a given field; to clarify key concepts/definitions in the literature; to examine how research is conducted on a certain; topic or field; to identify key characteristics or factors related to a concept; as a precursor to a systematic review; and to identify and analyse knowledge gaps" (p. 2). The aim of the scoping review was to synthesize and systematically map research that has assessed the effect of different classroom acoustic conditions on teachers' health and well-being as well as to identify gaps to inform future research. The following research question was formulated: What is known from the literature about the effect of classroom acoustic conditions on teachers' health and well-being?

Method

Protocol

The PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews; Tricco et al., 2018) was the protocol used for this scoping review. The PRISMA extension for scoping reviews website can be found at http://www.prisma-statement.org/Extensions/ScopingReviews.

Eligibility Criteria

To be included in the review, peer-reviewed journal articles needed to include a measure of teachers' health or well-being, taking into account the classroom acoustic environment. Peer-reviewed journal articles were included if they were written in English; included teachers across preschool, primary school, high school, or university; and included a measure of teachers' health or well-being. Only experimental studies were included (i.e., reviews were excluded). Studies examining online teaching were excluded. No restrictions were made on the publication dates or the type of study (i.e., quantitative, qualitative, or mixed-methods studies).

Information Sources

To identify potentially relevant documents, the following bibliographic databases were searched: ERIC, PubMed, Scopus, and Web of Science. The final search results were exported into .csv files where duplicates were removed.

Search

The database search was conducted on the November 28, 2022, by Author 1. The search term used for all databases was *classroom AND teacher AND (acoustic* OR nois* OR reverb*) AND (health OR wellbeing OR phys* OR mental* OR emotion* OR stress)*.

Selection of Sources of Evidence

All publications identified in the searches were evaluated by Author 1 and Author 2. Author 1 performed an initial screen of the titles, abstracts, and full text of the potentially relevant publications, and Author 2 subsequently screened the titles and abstracts of those same publications. Cohen's kappa comparing the agreement between the two screeners was 0.63, likely because Author 1 had the benefit of reading through the full text prior to Author 2. All discrepancies between Author 1 and Author 2 were resolved prior to further analysis.

Data Charting Process

Data charting refers to how relevant information from the articles were extracted. Data from eligible studies were charted to capture the relevant information on key study characteristics and detailed information on all metrics used to measure teachers' health and well-being.

Data Items

Data were abstracted on the following characteristics: the types of acoustic conditions that have been assessed, the types of measures used to assess health and

well-being, and the effect of the acoustic conditions on teachers' health and well-being.

Critical Appraisal

The Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies (Ciliska et al., 2010) was used to assess the methodological quality of the studies included in the review. Each study was assessed independently by Author 1 and Author 2, who both examined the full texts of the studies included in the review, and then the assessors came together to determine final ratings for each of the studies. Studies were assessed on up to six components where applicable: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Each of these components were scored and then rated as weak, moderate, or strong. For studies using multiple measures, the data collection methods were considered strong if at least one of the measures was valid and reliable. An overall global rating was also assigned to each study.

Synthesis of Results

Studies were grouped by the type of health or well-being measure used and summarized according to the effect of the acoustic conditions on teachers' health and well-being.

Results

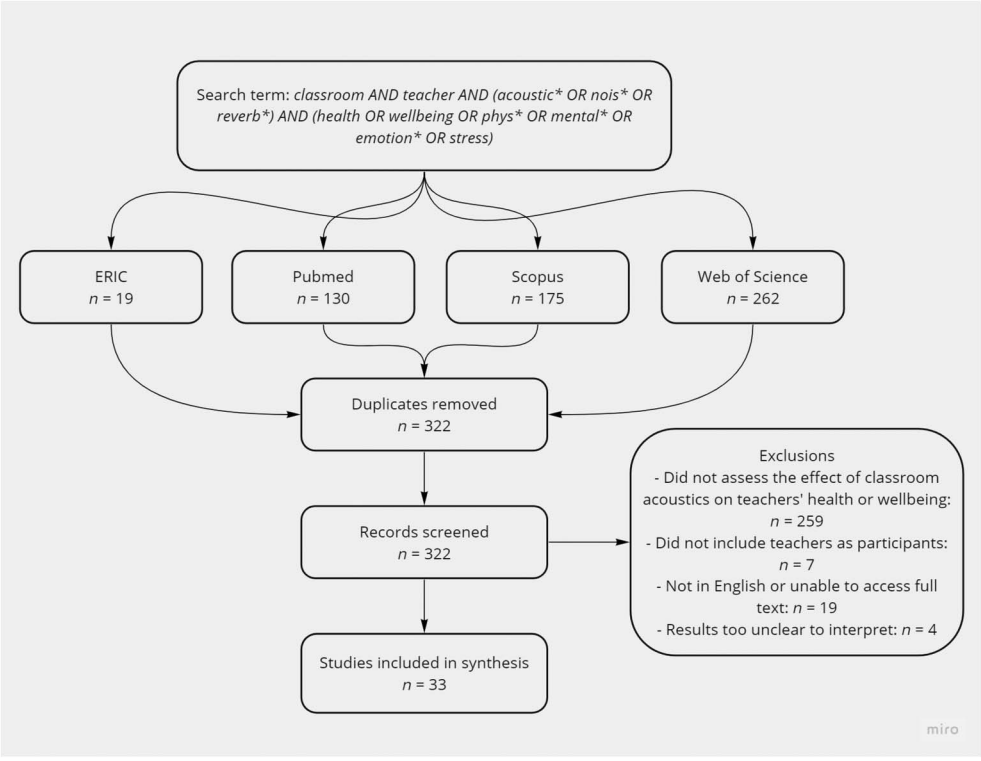
Selection of Sources of Evidence

The search and selection process of the studies to be included in the review is shown in Figure 1. After duplicates were removed, a total of 322 references were identified from searches of electronic databases. Based on the title and/or the abstract and full text, 289 articles were excluded for the following reasons: 259 did not assess the effect of classroom acoustics on teachers' health or well-being, seven did not assess teachers (e.g., assessed children), 19 did not have the full text available in English, and four had results reported in a way that were too unclear to interpret.

Characteristics and Results of Sources of Evidence

A summary of the studies included in the review is shown in Table 1. The publication years of the 33 studies included in the review are shown in Figure 2. The majority of articles have been published since 2012. The full

Figure 1. Search strategy and results.



range of education levels were assessed: five studies included preschool teachers, 23 studies included primary school teachers, 11 included high school teachers, and four included university teachers. Thirty studies assessed the effect of noise; 15 studies assessed the effect of reverberation; four studies assessed the effect of the number of students; two studies assessed the effect of clarity; and one study assessed the effect of EDT, definition, STI, and attenuation. Eighteen studies used self-report as the type of assessment of the acoustic parameters, and 17 used objective measures.

Measures of Health and Well-Being

Regarding the type of measure used to assess health and well-being, 27 articles used questionnaires (nine of these used validated questionnaires, 13 used unvalidated questionnaires developed for the study, and five used a combination of both), three studies used interviews, seven studies used physiological measures, and one study used cognitive tests. Table 2 provides a description of the measures used.

Critical Appraisal

Table 3 provides the results of the critical appraisal conducted by the two assessors. The components on confounders and blinding were not applicable for the majority of studies as they did not include an intervention. Similarly, withdrawals and dropouts were only considered if there was an intervention or a longitudinal design. Overall, 16 studies were rated as weak, 15 were rated as moderate, and two were rated as strong. Weak ratings were generally due to the use of less robust study designs and the use of unvalidated assessment tools.

Outcomes

A summary of the overall outcomes of the studies is shown in Table 1. The following describes the results in terms of noise level, reverberation, additional acoustic parameters, and the number of students in the class.

Effect of Noise

Figure 3 shows the effect of higher noise levels on teachers' health and well-being for different health categories. It can be seen that 22 different categories of health have been assessed, but the category that has been assessed by far the most is vocal health with 30 results (note that some studies have multiple results reported in a single article). The next highest is fatigue, with six results reported. The majority of results showed a negative effect of higher noise levels (61% of results). Thirty-six percent showed no effect, and 3% showed a positive effect of higher noise. Both of the studies showing a positive effect were vocal health studies, and the interpretation of these results will be unpacked more in the discussion.

For those articles that quantified noise exposure through objective measures, a further analysis was conducted. Figure 4 shows the effect of quantified noise exposure on teachers' health and well-being for different noise levels compared to the reference condition collated from the reviewed articles where objective measures were quantified and reported. It can be seen that a large range of noise levels has been assessed across the different studies. Higher noise levels tended to have a negative effect on teachers' vocal health across the range of noise levels studies (28 dBA to 117 dB max). Negative effects could also be seen for burnout and hearing. No effect was found for stress, fatigue, cognition, quality of life, or satisfaction at least for the noise-level ranges examined in these studies. Both negative and no effects were seen for mental health.

Effect of Reverberation

Figure 5 shows the effect of longer reverberation times on teachers' health and well-being for different health categories. Here, 15 different categories of health have been assessed. Again, the category that has been assessed the most is vocal health with 11 results, followed again by fatigue with four results. The majority of results showed no effect of longer reverberation times (58% of results), 39% showed a negative effect, and 3% (i.e., one result) showed a positive effect. Again, the interpretation of the positive effect will be unpacked more in the discussion.

For those articles that quantified reverberation times through objective measures, a further analysis was conducted. Figure 6 shows the effect of quantified reverberation time conditions on teachers' health and well-being for different reverberation times compared to the reference condition collated from reviewed articles where objective measures were quantified and reported. It can be seen that reverberation times between 0.3 and 0.8 s were assessed in the majority of studies. No effect of longer reverberation times was seen for vocal health, burnout, motivation, or quality of life. Both negative and no effects were seen for stress, fatigue, job satisfaction (although negative only effects were seen when the reverberation time range was extended), and social climate.

Effect of Other Acoustic Parameters

Regarding other acoustic parameters, two studies assessed the effect of speech clarity, and one of these studies assessed the effect of EDT, definition, STI, and attenuation. For clarity, one study showed a negative effect of poorer clarity on teacher's vocal health (Rantala & Sala, 2015), whereas the other study reported that clarity was

Table 1. General information for the 33 articles included in the review and effect on teachers' health and well-being.

Health/well-being category	Authors	Aim	Education level	Acoustic conditions	Health/well-being measure	Analysis	Effect of poorer acoustic conditions		
							Negative	None	Positive
Vocal health	Atará-Piraquive et al. (2021)	To determine the effect of a workplace vocal health promotion program and working conditions on voice functioning of college professors	University	**Self-report:** Noise too loud (rating 0 = *never* to 10 = *always*), good acoustics (rating 0–10), and number of students per class (average of 31 vs. 38).	**Questionnaire:** Voice-Related Quality of Life (validated in study) **Physiological measures:** Fundamental frequency and standard deviation, shimmer local (%), harmonics-to-noise ratio, sound pressure level and standard deviation, and maximum phonation time	Generalized estimating equations multivariate analysis of classroom conditions with voice functioning		x[a]	x[a]
	Banks et al. (2018)	To investigate the effect of classroom capacity on teachers' vocal fatigue	Primary school	**Self-report:** Classroom capacity, four levels: small room (i.e., office, special needs room, 5- to 10-student capacity), medium room (i.e., general core classroom, art room, 16- to 35-student capacity), large room (i.e., shop, music or performance room, 35+ student capacity), and very large room (i.e., gymnasium, cafeteria, auditorium, outdoors)	**Questionnaire:** Vocal Fatigue Index (validated)	Generalized linear model of classroom capacity with vocal fatigue factors	x		
	Bernstorf & Burk (1996)	To examine the association between the percentage of life span spent in teaching, teaching schedule, and classroom noise with vocal integrity in music teachers	Primary school	**Objective measures:** Classroom noise levels measured by dosimetry. Maximum noise levels ranged from 98.6 to 117.4 dBA.	**Questionnaire:** Voice Conservation Index (validated)	Correlation between maximum noise level and Voice Conservation Index	x		
	Cutiva & Burdorf (2015)	To assess the association between objectively measured and self-reported physical conditions at school with the presence of voice symptoms among teachers	Primary and high school	**Objective measures:** Noise levels inside (IQR 68–76 dBA) and outside (IQR 69–80 dBA) the classroom and reverberation times (0.91–2.01 s) **Self-report:** Noise and acoustic conditions (uncomfortable: *always*, *often*, *sometimes*, or *never*)	**Questionnaire:** Voice symptoms (unvalidated)	Multiple logistic regression multivariate analysis of classroom conditions with voice symptoms	x[b]	x[b]	
	Cutiva & Burdorf (2016)	To determine associations between work-related factors and voice complaints	Primary and high school	**Objective measures:** Noise levels inside (20% of classes ≥ 80 dBA) and outside (16% of classes ≥ 76 dBA) the classroom and reverberation times (31% of classes ≥ 2 s) **Self-report:** High background noise and poor acoustics (*always*, *often*, *sometimes*, or *never*)	**Questionnaire:** Voice symptoms (unvalidated)	Multiple logistic regression multivariate analysis of classroom conditions with voice symptoms	x[c]	x[c]	
	de Medeiros et al. (2008)	To establish the prevalence of dysphonia and associated factors	Primary school	**Self-report:** Noise generated in the classroom, within the school, and out of the school (*negligible* or *reasonable*, *high* or *unbearable*)	**Questionnaire:** Dysphonia (unvalidated)	Multinomial logistic regression analysis of classroom conditions with dysphonia	x		
	Devadas et al. (2017)	To investigate the prevalence and risk factors of voice problems among primary school teachers	Primary school	**Self-report:** Presence and level of noise in the classroom (scale not reported)	**Questionnaire:** Voice symptoms (unvalidated)	Pearson chi-square test to compare differences between teachers with and without voice problems for different risk factors. Multiple logistic regression analysis of different risk factors with voice problems	x		

(*table continues*)

Table 1. *(Continued).*

Health/well-being category	Authors	Aim	Education level	Acoustic conditions	Health/well-being measure	Analysis	Effect of poorer acoustic conditions		
							Negative	None	Positive
	Korn et al. (2015)	To characterize the presence of hoarseness and the risk factors	University	**Self-report:** Noise in classroom (*comfortable*, *tolerable*, *disturbing*, or *intolerable*) and number of students in class (< 30 to > 150)	**Questionnaire:** Hoarseness (unvalidated)	Chi-square test to compare hoarseness across categorical variables	x		
	Lyberg-Åhlander et al. (2015)	To investigate voice use, vocal behavior, and prevalence of voice problems	Primary and high school	**Self-report:** Noise noticeable and acoustics of classroom (0 = *completely disagree* to 4 = *agree completely*)	**Questionnaire:** Voice problems (unvalidated). Participants split into groups with and without voice problems for analysis **Physiological measures:** Laryngeal digital imaging	Mann–Whitney test comparing acoustics in groups with and without voice problems	x[d]	x[d]	
	Phadke et al. (2019)	To identify possible correlations between teachers' voice symptoms and their perception of noise	Preparatory and primary school	**Self-report:** Presence of noise sources (yes/no)	**Questionnaire:** Voice symptoms (unvalidated)	Chi-square test between the frequency voice symptoms and the proportion of teachers reporting noise sources	x[e]	x[e]	
	Pirilä et al. (2018)	To assess how teachers' voices behave during the delivery of lessons in core subjects	Primary school	**Objective measures:** Noise levels (55 dBA to 85 dB)	**Questionnaire:** Voice symptoms (validated) **Physiological measures:** Fundamental frequency, sound pressure level	Spearman's rank-order correlations between noise and voice variables	x[f]	x[f]	
	Rantala et al. (2012)	To investigate the connections between voice ergonomic risk factors found in classrooms and voice-related problems in teachers	Primary school	Noise assessed according to the Voice Ergonomic Assessment in Work Environment—Handbook and Checklist (no additional information on the assessment provided)	**Questionnaires:** Voice symptoms (validated) and Voice Handicap Index (validated)	Spearman rank correlation between noise and Voice Handicap Indices	x[g]	x[g]	
	Rantala & Sala (2015)	To research associations between classroom acoustic parameters and teachers' voice use and vocal health	Primary school	**Objective measures:** Noise levels (quiet classrooms $L_{90} \geq 41$ dB and noisy classrooms ≥ 42 dB), reverberation time ($M = 0.55$ s, $SD = 0.114$), early decay time ($M = 0.53$ s, $SD = 0.118$), clarity ($M = 4.5$ dB, $SD = 1.56$), definition ($M = 73\%$, $SD = 6.7$), speech transmission index ($M = 0.74$, $SD = 0.036$), attenuation ($M = 2.8$ dB, $SD = 0.86$)	**Questionnaires:** Voice tires (validated), Voice Handicap Index (validated), and laryngitis (unvalidated) **Physiological measures:** Fundamental frequency, sound pressure level, and the tilt of a sound spectrum	Spearman rank correlations between acoustic parameters and voice tires/Voice Handicap Indices	x		
	Sampaio et al. (2012)	To examine the relationship between voice handicap and professional vocal effort	Primary school	**Self-report:** Presence of excessive noise (yes/no)	**Questionnaire:** Voice Handicap Index (validated)	Multiple logistic regression analysis of classroom conditions with voice handicap	x		
	Ubillos et al. (2015)	To know the protective and risk factors associated with voice strain in teachers	Preschool to university	**Self-report:** Perception of noisy environment and number of students in class (0–20 vs. > 20)	**Questionnaire:** Voice problems (unvalidated)	Logistical regression models to investigate the causal factors of phoniatric treatments	x		
	van Houtte et al. (2012)	To identify vocal risk factors	Kindergarten to high school	**Self-report:** Level of noise outside the classroom, level of noise inside the classroom (*no noise* to *extremely noisy*), and acoustics in the classroom (*very good* to *extremely bad*; visual scale with no scale numbers)	**Questionnaire:** Voice disorders (unvalidated)	Multivariate logistic regression analysis of classroom conditions with voice disorders	x[h]	x[h]	

(*table continues*)

Table 1. *(Continued).*

Health/well-being category	Authors	Aim	Education level	Acoustic conditions	Health/well-being measure	Analysis	Effect of poorer acoustic conditions		
							Negative	None	Positive
Vocal health, stress, and burnout	Karjalainen et al. (2020)	To investigate the relationship between teachers' well-being and classroom acoustics	Primary school	**Objective measures:** Reverberation time 125 Hz (0.35–0.67 s), reverberation time 250 Hz to 4 kHz (0.30–0.70 s), clarity (2.7–9.2 dB), and ventilation system noise (28–42 dBA; 47–61 dBC)	**Questionnaires:** Voice Handicap Index (validated), Perceived Stress Questionnaire (validated), Copenhagen Burnout Inventory (validated), and Teachers' Sense of Efficacy Scale: Classroom Management subscale (validated)	Nonparametric correlations between teachers' well-being and classroom acoustics	x[j]	x[j]	
Vocal health and fatigue	Kristiansen et al. (2016)	To investigate whether acoustical refurbishment of classrooms affected teachers' perceived noise exposure during teaching and noise-related health symptoms	Primary and high school	**Objective measures:** Reverberation time (pre-intervention: 0.57–0.68 s, post-intervention: 0.4 s) and activity noise (pre-intervention: 69 dBA, post-intervention: 67 dBA) **Self-report:** Noise exposure (*nearly all the time*, *¾ of the time*, *½ of the time*, *¼ of the time*, *rarely or very little*, and *never*)	**Questionnaires:** Noise disturbance (unvalidated), voice symptoms (unvalidated), and Swedish Occupational Fatigue Inventory–20 (validated)	Linear mixed models of symptoms with refurbishment status	x[j]	x[j]	
Vocal health, fatigue, and cognition	Kristiansen et al. (2014)	To investigate if noise posed a risk of impairment of hearing and to study the association between classroom acoustical conditions, noise exposure, vocal symptoms, and cognitive fatigue	Primary and high school	**Objective measures:** Reverberation time (0.39–0.83 s) and noise (62–83 dBA)	**Questionnaires:** Stress and Energy Inventory (validated); voice symptoms, mental fatigue, exertion (unvalidated) **Cognitive tests:** Sustained Attention to Response Test and Two-Back Test completed before and after the workday	Spearman's rank correlations of health with noise levels	x[k]	x[k]	
Vocal health and hearing	Redman et al. (2022)	To evaluate the voice and hearing status of voice instructors before and after lessons and relate these evaluations with voice and noise dosimetry taken during lessons	University	**Objective measures:** Reverberation time (0.21–0.37 s) and noise (83–88 dBA)	**Physiological measures (voice):** Voice level, fundamental frequency, Acoustic Voice Quality Index, cepstral peak prominence smoothed, pitch strength **Physiological measures (hearing):** Thresholds	Linear mixed-models assessing voice and hearing pre- and post-lesson	x[l]	x[l]	x[l]
Vocal health and physical and mental health symptoms	Lin et al. (2020)	To investigate environmental concerns in schools, teacher-reported symptoms, and performance	Primary and high school	**Self-report:** Excessive noise and excessive echo	**Questionnaire:** Sinus problems, allergies/congestion, headache, sneezing, throat irritation, fatigue/drowsiness, eye irritation, frequent colds, cough without cold, skin irritation, inability to focus, wheezing, nausea, asthma attacks (unvalidated)	Unconditional logistic regression of health symptoms for classroom conditions	x[m]	x[m]	
	Redel-Macías et al. (2021)	To study the health problems in dance teachers in taking into account the noise and thermal environment	Not reported	**Objective measures:** Noise levels (54–97 dBA)	**Questionnaire:** General discomfort, headaches, irritability/stress, sleep disturbances, deafness, vocal nodules/edema/swellings (unvalidated)	Prevalence of discomfort and problems associated with noise in the classes	x[n]	x[n]	

(*table continues*)

Table 1. *(Continued).*

Health/well-being category	Authors	Aim	Education level	Acoustic conditions	Health/well-being measure	Analysis	Effect of poorer acoustic conditions		
							Negative	None	Positive
Hearing	Novanta et al. (2020)	To assess if classroom noise reduces teachers' otoacoustic emissions	Primary school	**Objective measures:** Noise levels (M = 76.9 ± 5.4 dBA, range: 59.1 ± 4.3 to 90 ± 7.1)	**Physiological measures:** Distortion–product otoacoustic emissions amplitude and signal-to-noise ratio before and after teaching	Paired t test comparing results before and after teaching. Pearson correlation coefficients were used to determine associations between noise level and the differences between physiological measures	x		
Physical and mental health	Bulunuz et al. (2021)	To assess the noise sensitivity and coping efforts of classroom teachers who intensely experienced noise phenomenon in their school	Primary school	Noise not measured, but interviews asked how any classroom noise present affected the teachers	**Interview:** How noise affects the teachers	Qualitative analyses. Themes were hypersensitivity, migraine/headache, tinnitus, difficulty focusing, tiredness, anger	x		
Fatigue and job satisfaction	Kristiansen et al. (2013)	To investigate the effects of perceived noise exposure and classroom reverberation on measures of well-being	Primary and high school	**Objective measures:** Reverberation time (low schools 0.41–0.47 s, medium schools 0.50–0.53 s, and high schools 0.59–0.73 s) **Self-report:** Noise exposure (*never/rare*, *a quarter to a half of the work time*, and ≥ ¾ *of the time*)	**Questionnaires:** Swedish Occupational Fatigue Inventory–20 (validated), job satisfaction and interest in leaving the job (unvalidated)	Mixed-model regression models of fatigue and job satisfaction with acoustical factors	x[o]	x[o]	
Quality of life	Levandoski & Zannin (2022)	To compare the quality of life of teachers working at schools with different acoustic conditions	Not reported	**Objective measures:** Noise levels outside (69 dB vs. 73.5 dB), noise levels inside (54.9 dB vs. 74 dB), reverberation time (0.88–0.91 s vs. 1.67–1.76 s)	**Questionnaire:** World Health Organization Quality of Life Questionnaire (validated)	Mann–Whitney test comparing quality of life between two schools with different acoustics		x	
Mental health	Grebennikov & Wiggins (2006)	To examine the relationship between exposure to classroom noise and the psychological well-being of teachers	Preschool	**Objective measures:** Noise levels (73.9–85.3 dB)	**Questionnaires:** Personal Strain Questionnaire (validated), General Health Questionnaire (validated), life style index (validated)	t test comparing mental health questionnaire results with low and high noise exposure groups	x[p]	x[p]	
	de Alcantara et al. (2019)	To analyze the relationship between health, work characteristics, education, and skills on the work ability of teachers	Preschool to Grade 12	**Self-report:** Need to raise voice because of noise (1 = *never or almost never* to 4 = *often*)	**Interview:** Health status (use of anxiolytic medication, occupational illness, sleep problems) and work ability	Structural equation modeling to assess interrelations between determinants of work ability	x		
Absenteeism	Maia et al. (2019)	To identify multiple exposures to the risk of work absenteeism among Brazilian schoolteachers	Not reported	**Self-report:** Exposure to intense noise	**Interview:** Absenteeism reasons (emotional problems, voice problems, respiratory problems)	Poisson regression models of absenteeism reasons with wok conditions	x[q]	x[q]	
Stress	Tomek & Urhahne (2022)	To examine how teachers with different coping styles reacted to school noise	Primary and high school	**Self-report:** Noise stress (5-point Likert scale from 1 = *totally disagree* to 5 = *totally agree*)	**Questionnaire:** Stress, strain, and strain consequences (unvalidated, but questions based on validated questionnaires)	Correlations between noise stress and threat appraisal, vocal fatigue, hearing problems, and burnout	x[r]		
Stress, fatigue, and heart rate	Tiesler & Oberdörster (2008)	To assess noise as a stressor in teachers	Not reported	**Objective measures:** Reverberation time (classrooms < 0.5 s and classrooms > 0.5 s)	**Physiological measures:** Heart rate	Descriptive statistics of noise level and heart rate before and after acoustic treatment	x		

(*table continues*)

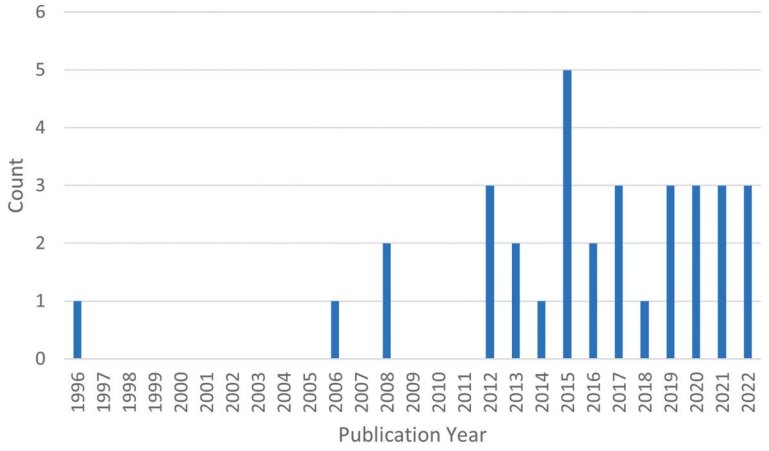
Table 1. *(Continued).*

Health/well-being category	Authors	Aim	Education level	Acoustic conditions	Health/well-being measure	Analysis	Effect of poorer acoustic conditions		
							Negative	None	Positive
Social climate and job satisfaction	Persson et al. (2013)	To investigate how reverberation time and hearing ability were associated with schoolteachers' perceptions of the social climate at work and their intentions to stay on the job	Not reported	**Objective measures:** Reverberation time (low schools 0.41–0.47 s, medium schools 0.50–0.53 s, and high schools 0.59–0.73 s)	**Questionnaire:** General Nordic Questionnaire for Psychological and Social Factors at Work (validated) and intention to stay at work (unvalidated) **Physiological measures:** Hearing thresholds and distortion product otoacoustic emissions	Univariate ANOVA comparing questionnaires across schools with different reverberation times	x[s]	x[s]	
Satisfaction	Radwan & Issa (2017)	To evaluate the well-being of teachers as it pertains to their perception of their classrooms' indoor environment	Not reported	**Objective measures:** Noise level (means for school types of 54.24, 57.49, and 61.15 dB)	**Questionnaire:** Satisfaction with the acoustic environment (unvalidated)	Kruskal–Wallis test of teachers' satisfaction with classroom acoustics between different school types		x	

Note. IQR = interquartile range; ANOVA = analysis of variance.

[a]The number of students in class was significantly associated with a small decrease in vocal level, and self-reported good classroom acoustics were significantly associated with a small decrease in maximum phonation time (i.e., positive effects on voice of poorer acoustics). No other significant associations were found. [b]The presence of voice symptoms was related to high noise levels measured outside the school and self-reported poor acoustics in the classroom. No significant associations between voice symptoms and high noise levels measured in the classroom, long reverberation time measured in the classroom, and self-reported noise in the classroom were found. [c]Self-reported high noise level in the classroom was significantly associated with the incidence of voice complaints; however, self-reported poor acoustics as well as objective measures of noise inside and outside the school and classroom reverberation time were not significant. Additionally, self-reported poor acoustics in the classroom was significantly associated with chronic voice complaints; however, self-reported high noise levels as well as objective measures of noise inside and outside the school and classroom reverberation time were not significant. [d]Worse ratings for the group with voice problems compared to the group with no problems for "The classroom acoustics help me talk comfortably," "The classroom is difficult to talk in," "I need to increase the power of my voice to make myself heard even with just a little noise in the classroom," "My voice gets muffled by the classroom acoustics," and "The classroom acoustics has influence on my way of talking (with the pupils present)." However, there was no difference between groups for "There is an echo in the classroom," "The noise made by the pupils is very noticeable in the classroom," "The noise from the ventilation is noticeable," "The noise from audio/visual resources is noticeable," and "The noise coming from outside of the classroom is noticeable." [e]Significant association between frequent laryngeal or neck pain symptoms and noise from other classrooms. No association with traffic noise, sport area noise, student noise, external noise, or aeration noise. [f]Significant correlation between noise and dry throat and noise and throat irritation. Nonsignificant correlation between noise and vocal fatigue. [g]Significant correlation between noise and physical voice handicap. Nonsignificant between noise and symptoms, functional voice handicap, or emotional voice handicap. [h]Significant association between voice disorders and noise inside the classroom. Not significant for noise outside the classroom or classroom acoustics. [i]Higher degree of burnout was significantly associated to higher ventilation system noise. Voice symptoms associated with higher ventilation system noise. Association of ventilation system noise with stress or self-efficacy was not significant. Reverberation and clarity were not significantly associated with voice symptoms, stress, burnout, or self-efficacy. [j]Refurbishment (better acoustics) associated with less noise disturbance from equipment. No significant effect of refurbishment on noise disturbance from pupils, other classes, ventilation/machines, or voice symptoms or fatigue. [k]Significant correlation of increased noise with increased changes in voice symptoms. Correlation of noise with energy, stress, fatigue, strenuous workday, and cognitive measures was not significant. [l]Pitch strength increased for females but did not change for males postlesson, cepstral peak prominence smoothed increased for females and decreased for males, and acoustic voice quality index improved for females and worsened for males. No changes in hearing were found. [m]Significant acoustic-related symptoms were headache, throat irritation, fatigue, coughing without cold, and inability to focus. Sinus problems, allergies/congestion, sneezing, eye irritation, frequent colds, skin irritation, wheezing, nausea, and asthma attacks are not significant. [n]Greater than 50% of participants reported noise associated with general discomfort, headaches, irritability/stress, and vocal nodules/edema/swellings. Less than 50% reported sleep disturbances and deafness. [o]Reverberation time and self-reported noise exposure had a significant negative effect on job satisfaction. Neither reverberation time nor noise exposure had a significant influence on the physical aspect of fatigue. Reverberation time and noise had significant effects on lack of energy after work. Noise but not reverberation time had an effect on lack of motivation. Noise but not reverberation time had an effect on sleepiness after work. Reverberation time and noise were significantly associated with interest in leaving job. [p]Significant effect for high compared to low noise group for interpersonal strain, regression, and displacement. No significant effect for vocational strain, psychological strain, physical strain, denial, repression, compensation, projection, intellectualization, reaction formation, defense, or chronic distress. [q]Strongest associations of exposure to intense noise and absenteeism due to stressors at school, emotional problems, and voice problems. [r]Correlations were significant for teachers with all coping types, but teachers of the risk types (Type A and burnout type) were more vulnerable to school noise than teachers of the healthy type. [s]Teachers who worked in classrooms with long reverberation times perceived their social climate to be more competitive, more rigid and rule based, conflict laden, and less relaxing and comfortable and were less positive about their intentions to stay on the job than teachers who worked in classrooms with short or medium reverberation times. No difference for the social climate being encouraging and supportive, or distrustful and suspicious.

Figure 2. Publication years of the 33 journal articles included in the review.



not significantly associated with voice symptoms, stress, burnout, or self-efficacy (Karjalainen et al., 2020). For decay time, definition, STI, and attenuation, a negative effect of poorer acoustic conditions on teacher's vocal health was found (Rantala & Sala, 2015).

Effect of the Number of Students

Regarding the number of students in class, only five results were reported across four articles, with all articles assessing the effect on vocal health. Three results showed a negative effect of a larger number of students (Banks et al., 2018; Korn et al., 2015; Ubillos et al., 2015), one result showed no effect (Atará-Piraquive et al., 2021), and one result showed a positive effect (Atará-Piraquive et al., 2021). Again, the interpretation of the positive effect will be unpacked more in the discussion.

Discussion

This scoping review aimed to determine what is known about the effect of classroom acoustic conditions on teachers' health and well-being. Thirty-three articles met the criteria to be included in the review. The results of the studies were analyzed according to the effect of classroom acoustics on different aspects of teachers' health and well-being.

Summary of Findings

By far, the most researched health category was vocal health. However, many other aspects of health have also been studied, but only in a small number of studies. Overall, higher noise levels (measured across the range of 28 dBA to 117 dB max) had a negative effect on teachers' health and well-being in the majority of results reported across the studies (61%), and a higher number of students (measured across the range of 5–150+ students) also had a negative effect in the majority of results (60%). For reverberation times, a negative effect of longer reverberation time (measured across the range of 0.2–2 s) on teachers' health and well-being was seen in 39% of results with the majority of results showing no effect (58%).

Discussion of Findings

These results show that poor classroom acoustic conditions can have a negative effect on teachers' health and well-being. There are several reasons why poor acoustic conditions affect people's health and well-being. Noise-induced hearing loss can occur when people are exposed to loud sounds over a period of time as the noise affects the functioning of the cochlea. This hearing loss may be a temporary shift in hearing levels or a permanent shift if the damage is irreversible. Exposure to noise may also result in abnormal loudness perception and tinnitus (Berglund et al., 1999). Noise exposure can also have cardiovascular and physical effects as noise exposure can activate the autonomic and hormonal systems (Berglund et al., 1999). This can cause temporary changes to heart rate and blood pressure but may also lead to permanent effects such as hypertension and heart disease (Berglund et al., 1999). Additionally, noise can have negative effects on mental health producing symptoms such as anxiety, emotional stress, argumentativeness, changes in mood, social conflicts, and psychiatric disorders (Berglund et al., 1999). Noise can also adversely affect cognitive performance (Berglund et al., 1999).

Noise is a problem for teachers for all of the reasons above, but it has the additional issue that teachers need to use their voice to teach regardless of the noise that may be present. Noise in the classroom is problematic as it is

Table 2. Descriptions of measures used in reviewed studies.

Outcome	Measure type	Studies	Measure name	Description
Vocal health	Questionnaire (validated)	Atará-Piraquive et al. (2021)	Voice-Related Quality of Life	Questionnaire that evaluates physical functioning and social–emotional domains. Ten items rated on how much of a problem it is on a 5-point Likert scale
		Banks et al. (2018)	Vocal Fatigue Index	Questionnaire that evaluates vocal fatigue in terms of tiredness of voice and voice avoidance, physical discomfort associated with voicing, and improvement of symptoms with rest. Nineteen items rated on frequency on a 5-point Likert scale
		Bernstorf & Burk (1996)	Voice Conservation Index	Questionnaire that evaluates auditory and vocal performance in various environmental situations and conditions
		Rantala et al. (2012) Rantala & Sala (2015) Sampaio et al. (2012) Karjalainen et al. (2020)	Voice Handicap Index	Questionnaire that evaluates physical, functional, and emotional handicap. Thirty items rated on frequency on a 5-point Likert scale
		Pirilä et al. (2018) Rantala et al. (2012) Rantala & Sala (2015) (voice tires question only)		Questionnaire on the most typical voice symptoms: voice tires easily, hoarseness, voice breaks, aphonia lasting at least a couple of minutes during speaking, difficulty in being heard, throat clearing, and sore throat or globus in the throat (Simberg et al., 2001)
	Questionnaire (unvalidated)	Cutiva & Burdorf (2015) Cutiva & Burdorf (2016)		Questionnaire developed for the study including questions on demographics; presence, frequency, and duration of voice symptoms in the past month; working conditions; and health conditions
		de Medeiros et al. (2008)		Questionnaire developed for the study including questions on social and demographic themes, voice health, general and mental health, and work environment and organization
		Devadas et al. (2017)		Questionnaire developed for the study including questions on the prevalence vocal problems, variables associated with vocal problems, vocal symptoms, physician or speech-language pathologist consultation, the effect of vocal problems, and knowledge of voice care
		Korn et al. (2015)		Voice self-evaluation forms prepared by the Brazilian Ministry of Labor including questions on demographics, workplace, voice care, lifestyle, and quality of life
		Lyberg-Åhlander et al. (2015)		Questionnaire developed for the study including questions on background information; room acoustics, perception of noise sources, and other issues related to the environment; and voice problems, vocal behavior, and statements about skills in voice use
		Phadke et al. (2019)		Questionnaire developed for the study including questions on demographics, frequency and severity of voice symptoms from the past 6 months, and school and classroom location and conditions

(*table continues*)

Table 2. *(Continued).*

Outcome	Measure type	Studies	Measure name	Description
		Rantala & Sala (2015)		Yes/no questions if the teacher had laryngitis or other infections of the larynx diagnosed by a physician in the past 12 months
		Ubillos et al. (2015)		Questionnaire developed for the study including questions on demographics, working conditions, voice training, perception of noisy environments, vocal cord abuse, voice health, and health-related habits
		van Houtte et al. (2012)		Questionnaire developed for the study including questions on voice disorders, personal and work-related characteristics, and hobbies/lifestyle
		Kristiansen et al. (2016)		Questionnaire developed for the study assessing noise exposure and disturbance, and voice symptoms
		Kristiansen et al. (2014)		One question assessing the teachers' voice symptoms
		Redel-Macías et al. (2021)		Questionnaire developed for the study including questions on vocal nodules/edema/swellings
	Physiological measures	Pirilä et al. (2018) Rantala & Sala (2015) Redman et al. (2022) Atará-Piraquive et al. (2021) Lyberg-Åhlander et al. (2015)	Sound pressure level	Measures the loudness of the teacher's voice
		Pirilä et al. (2018) Rantala & Sala (2015) Redman et al. (2022) Atará-Piraquive et al. (2021) Lyberg-Åhlander et al. (2015)	Fundamental frequency	Measures the voice pitch
		Atará-Piraquive et al. (2021)	Shimmer local	The average absolute difference between the amplitudes of consecutive periods, divided by the average amplitude
		Atará-Piraquive et al. (2021)	Harmonics-to-noise ratio	Ratio between periodic and nonperiodic components of a speech sound
		Atará-Piraquive et al. (2021)	Maximum phonation time	Maximum amount of time a person can sustain phonation of "ah"
		Rantala & Sala (2015)	Spectral tilt	Relationship of voice energy levels between the level of 50 Hz to 1 kHz and the level of 1–5 kHz. The higher the value, the more hyperfunctional the voice quality
		Redman et al. (2022)	Acoustic Voice Quality Index	A weighted metric combining time and frequency to measures dysphonia severity. Higher values represent a higher grade of dysphonia
		Redman et al. (2022)	Cepstral peak prominence smoothed	A smoothed measure of the amplitude of the cepstral peak, normalized for overall signal amplitude via a linear regression line calculated relating to frequency cepstral. Higher values represent better voice functioning
		Redman et al. (2022)	Pitch strength	The correlation coefficient between the ideal signal emitted by the vocal folds and the actual one produced by the speaker. The higher the value, the better the voice quality

(*table continues*)

Table 2. *(Continued).*

Outcome	Measure type	Studies	Measure name	Description
Hearing	Questionnaire (unvalidated)	Redel-Macías et al. (2021)		Questionnaire developed for the study including a question on deafness
	Physiological measures	Redman et al. (2022) Persson et al. (2013)	Hearing thresholds	The lowest sound level that the teacher can hear
		Novanta et al. (2020) Persson et al. (2013)	Distortion–product otoacoustic emissions amplitude and signal-to-noise ratio	A measure of outer hair cell integrity and cochlear function
Physical health	Questionnaire (validated)	Kristiansen et al. (2016) Kristiansen et al. (2013)	Swedish Occupational Fatigue Inventory–20	Questionnaire with five dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness. Twenty items are rated on degree of problem on a 7-point Likert scale
	Questionnaire (unvalidated)	Kristiansen et al. (2014)		One question assessing the teachers' degree of exertion during the workday
		Lin et al. (2020)		Questionnaire developed for the study including questions on demographics, sinus problems, allergies/congestion, headache, sneezing, throat irritation, fatigue/drowsiness, eye irritation, frequent colds, cough without cold, skin irritation, inability to focus, wheezing, nausea, asthma attacks
		Redel-Macías et al. (2021)		Questionnaire developed for the study including questions on general discomfort, headaches, and sleep disturbances
		Tomek & Urhahne (2022)		Questionnaire developed for the study including questions on stress, strain, and strain consequences adapting questions from validated questionnaires
	Interview	Bulunuz et al. (2021)		Semistructured interview on the effects of noise, how teachers protect themselves and their students from noise, and what can be done about the noise
		Maia et al. (2019)		Interview on absenteeism reasons (including voice problems and respiratory problems)
	Physiological measures	Tiesler & Oberdörster (2008)	Heart rate	Number of times the teacher's heart beats in a minute
Mental well-being	Questionnaire (validated)	Karjalainen et al. (2020)	Perceived Stress Questionnaire	Questionnaire that evaluates cognitive perceptions of stress. Thirty items are rated on frequency on a 4-point Likert scale
		Karjalainen et al. (2020)	Copenhagen Burnout Inventory	Questionnaire with three subscales: personal burnout, work-related burnout, and client-related burnout. Nineteen items are rated on a 5-point Likert scale
		Karjalainen et al. (2020)	Teachers' Sense of Efficacy Scale: Classroom Management subscale	Questionnaire targeting teachers' ability to manage the classroom. Eight items are rated on a 9-point Likert scale
		Kristiansen et al. (2014)	Stress and Energy Inventory	Checklist that assesses self-reported arousal
		Levandoski & Zannin (2022)	World Health Organization Quality of Life Questionnaire	Questionnaire with four domains, physical, psychological, social relations, and the environment, plus two questions on the individual perception of quality of life. Twenty-six items are rated on a 5-point Likert scale

(*table continues*)

Table 2. *(Continued).*

Outcome	Measure type	Studies	Measure name	Description
		Grebennikov & Wiggins (2006)	Personal Strain Questionnaire	Questionnaire with four subscales: vocational strain, psychological strain, interpersonal strain, and physical strain. Forty items are rated in terms of agreement on a 5-point Likert scale
		Grebennikov & Wiggins (2006) de Medeiros et al. (2008)	General Health Questionnaire	Screening test on emotional distress and social dysfunction. Sixty items rated on a 4-point scale
		Grebennikov & Wiggins (2006)	Life style index	Questionnaire with eight scales: compensation, denial, displacement, intellectualism, projection, reaction formation, regression, and repression. Ninety-seven items are rated as yes/no
		Persson et al. (2013)	General Nordic Questionnaire for Psychological and Social Factors at Work	Questionnaire with five items on the social climate at the workplace: competitive, encouraging and supportive, distrustful and suspicious, relaxed and comfortable, and rigid and rule based. Items are rated on a 5-point Likert scale
	Questionnaire (unvalidated)	Kristiansen et al. (2014)		One question assessed mental fatigue
		Redel-Macías et al. (2021)		Questionnaire developed for the study including a question on irritability/stress
		Kristiansen et al. (2013)		One question assessed job satisfaction, and one question assessed interest in leaving the job
		Tomek & Urhahne (2022)		Questionnaire developed for the study including questions on stress, strain, and strain consequences adapting questions from validated questionnaires
		Persson et al. (2013)		One question assessing to what degree the social climate at work is conflict laden. One question assessing to what degree teachers want to stay in their workplace
		Radwan & Issa (2017)		Questionnaire developed for the study on the teachers' satisfaction with their classrooms adapting questions from validated questionnaires
	Interview	Bulunuz et al. (2021)		Semistructured interview on the effects of noise, how teachers protect themselves and their students from noise, and what can be done about the noise
		de Alcantara et al. (2019)		Interview on the teacher's health status (use of anxiolytic medication, occupational illness, sleep problems) and work ability
		Maia et al. (2019)		Interview on absenteeism reasons (including emotional problems), voice problems, respiratory problems
	Cognitive tests	Kristiansen et al. (2014)	Sustained Attention to Response Test	Assesses the teachers' ability to inhibit responses
		Kristiansen et al. (2014)	Two-Back Test	Assesses teachers' working memory functioning

subject to the Lombard effect and the café effect. The Lombard effect refers to the tendency of a speaker to increase their voice when there is noise present so that they can hear themselves and others can hear them (Lombard, 1911). Speakers may also enhance their visible articulatory movements to aid speech intelligibility for the listener (Garnier et al., 2018). This vocal increase leads to the café effect, which produces a rising level of activity noise (Whitlock & Dodd, 2008). This is further exacerbated by the reverberation in the classroom. When people raise their voice due to noise, it decreases their vocal comfort and control and increases feelings of vocal fatigue (Bottalico et al., 2015; Sierra-Polanco et al., 2021). People raise their voice by around 0.24dB for each dB increase

Table 3. Critical appraisal quality ratings of reviewed studies.

Reference	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and dropouts	Global rating
Atará-Piraquive et al. (2021)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Banks et al. (2018)	Strong	Weak			Strong		Moderate
Bernstorf & Burk (1996)	Moderate	Weak			Strong		Moderate
Bulunuz et al. (2021)	Moderate	Weak			Weak		Weak
Cutiva & Burdorf (2016)	Weak	Weak			Weak	Moderate	Weak
Cutiva & Burdorf (2015)	Weak	Weak			Weak		Weak
de Alcantara et al. (2019)	Strong	Weak			Weak		Weak
de Medeiros et al. (2008)	Strong	Weak			Strong		Moderate
Devadas et al. (2017)	Moderate	Weak			Weak		Weak
Grebennikov & Wiggins (2006)	Moderate	Weak			Strong		Moderate
Karjalainen et al. (2020)	Moderate	Weak			Strong		Moderate
Korn et al. (2015)	Moderate	Weak			Weak		Weak
Kristiansen et al. (2016)	Weak	Weak	Weak	Moderate	Strong	Strong	Weak
Kristiansen et al. (2014)	Weak	Moderate			Moderate	Weak	Weak
Kristiansen et al. (2013)	Moderate	Weak			Strong		Moderate
Levandoski & Zannin (2022)	Moderate	Weak			Strong		Moderate
Lin et al. (2020)	Strong	Weak			Weak		Weak
Lyberg-Åhlander et al. (2015)	Moderate	Weak			Strong		Moderate
Maia et al. (2019)	Strong	Weak			Weak		Weak
Novanta et al. (2020)	Moderate	Weak			Strong	Strong	Moderate
Persson et al. (2013)	Weak	Weak			Strong		Weak
Phadke et al. (2019)	Moderate	Weak			Weak		Weak
Pirilä et al. (2018)	Moderate	Weak			Moderate		Moderate
Radwan & Issa (2017)	Moderate	Weak			Weak		Weak
Rantala et al. (2012)	Moderate	Weak			Strong		Moderate
Rantala & Sala (2015)	Moderate	Weak			Strong		Moderate
Redel-Macías et al. (2021)	Moderate	Weak			Weak		Weak
Redman et al. (2022)	Moderate	Moderate			Strong		Moderate
Sampaio et al. (2012)	Moderate	Weak			Strong		Moderate
Tiesler & Oberdörster (2008)	Weak	Weak			Strong	Weak	Weak
Tomek & Urhahne (2022)	Moderate	Weak			Strong		Moderate
Ubillos et al. (2015)	Moderate	Weak			Weak		Weak
van Houtte et al. (2012)	Weak	Weak			Weak		Weak

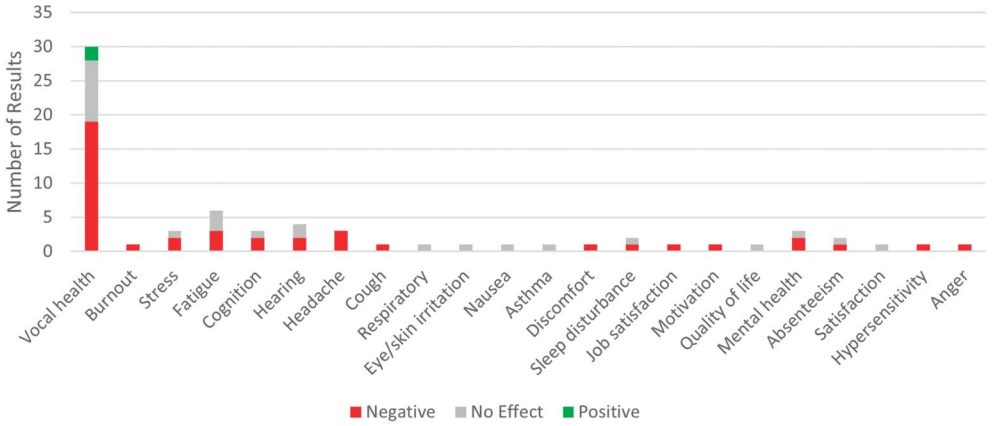
in the noise level (Bottalico et al., 2015). Speaking in a louder volume is not the only vocal change elicited by noise. People also have longer word duration, a higher fundamental frequency, and decreased spectral tilt (Van Summers et al., 1988). Having to speak in a louder voice over a long period of time improves speech intelligibility for the listener but may be harmful for the speaker, as seen in many of the reviewed studies.

Interestingly, two studies reported a positive effect of higher noise levels, number of students, or reverberation time (in this case, self-reported room acoustics) on teachers' vocal health. These studies were by Redman et al. (2022) and Atará-Piraquive et al. (2021).

Redman et al. (2022) found that voice quality metrics of pitch strength increased for females (indicating better vocal functioning) but did not change for males, cepstral peak prominence smoothed increased for females (indicating better vocal functioning) and decreased for males (indicating poorer vocal functioning), acoustic voice quality index improved for females (indicating better vocal functioning) and worsened for males (indicating poorer vocal functioning) postteaching in classrooms with reverberation times of 0.21–0.37 s and noise levels of 83–88 dBA compared to preteaching. Reasons for the improved vocal functioning postteaching for females were not reported. However, in all subjects, the voice-level mean increased, and standard deviation of the fundamental frequency decreased, indicating vocal fatigue.

Atará-Piraquive et al. (2021) did not find a statistically significant association with self-reported classroom

Figure 3. Effect of higher noise levels (negative, no effect, positive) on teachers' health and well-being for different health categories.



noise, acoustics, or a number of students in class and voice-related quality of life, but they did find, however, that the number of students in class was significantly associated with a small decrease in vocal level and self-reported good classroom acoustics were significantly associated with a small decrease in maximum phonation time. The authors suggest that these professors have learned to use their voice in a safer way when they have larger classes, but when they have good acoustic conditions, they do not monitor their voice as well. This shows the importance of raising awareness about vocal health techniques as well as improving classroom acoustic conditions.

Limitations of the Studies

There are several limitations of the reviewed studies, which create gaps to be filled by future research. First, more studies are needed that use physiological measures of a range of health and well-being outcomes in addition to self-report questionnaires or interviews. Of the 33 articles in this review, only six used physiological measures compared to 30 that included self-report questionnaires or interviews. Self-reports can provide helpful information; however, they are open to response bias. Questions may be interpreted differently by different people. Additionally,

Figure 4. Effect of quantified noise exposure (negative, no effect) on teachers' health and well-being for different noise levels compared to the reference condition collated from reviewed articles. Lines represent when a range of levels were studied. Arrows indicate when levels above/below indicated level were investigated. 1 = Bernstorf and Burk (1996); 2 = Cutiva and Burdorf (2015); 3 = Rantala and Sala (2015); 4 = Karjalainen et al. (2020); 5 = Kristiansen et al. (2016); 6 = Kristiansen et al. (2014); 7 = Pirilä et al. (2018); 8 = Karjalainen et al. (2020); 9 = Karjalainen et al. (2020); 10 = Kristiansen et al. (2016); 11 = Kristiansen et al. (2014); 12 = Kristiansen et al. (2014); 13 = Novanta et al. (2020); 14 = Levandoski and Zannin (2022); 15 = Grebennikov and Wiggins (2006); 16 = Radwan and Issa (2017).

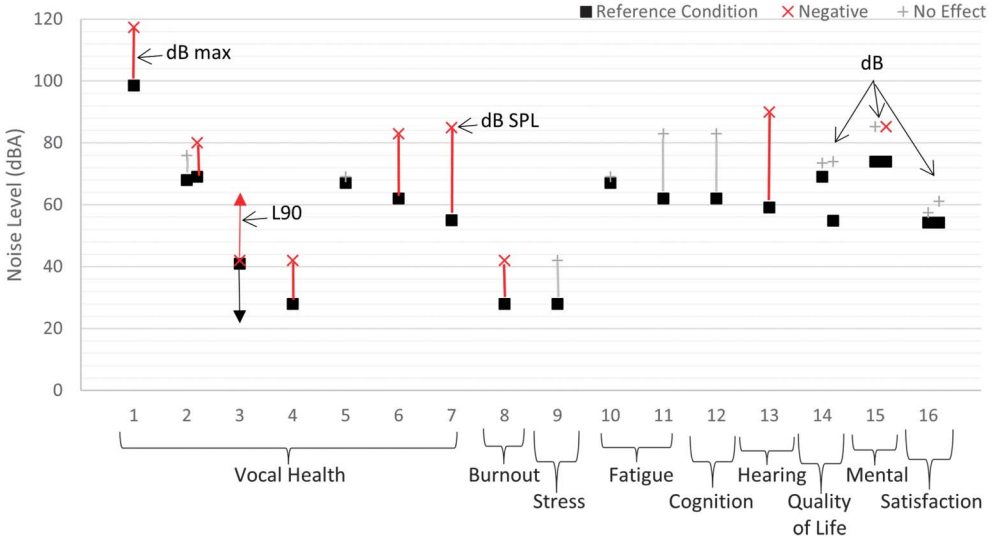
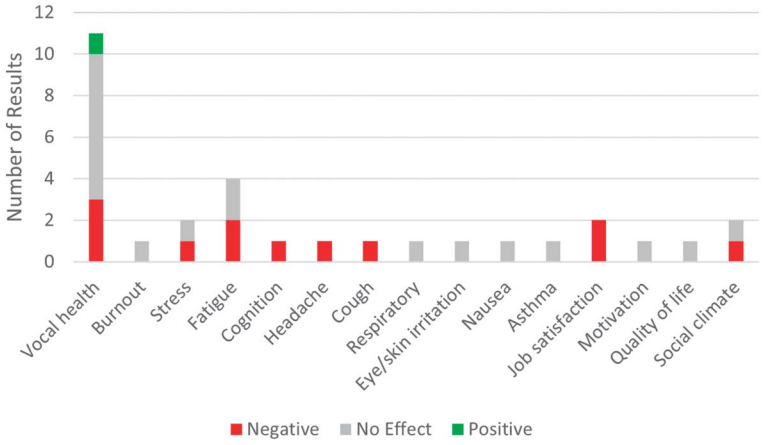


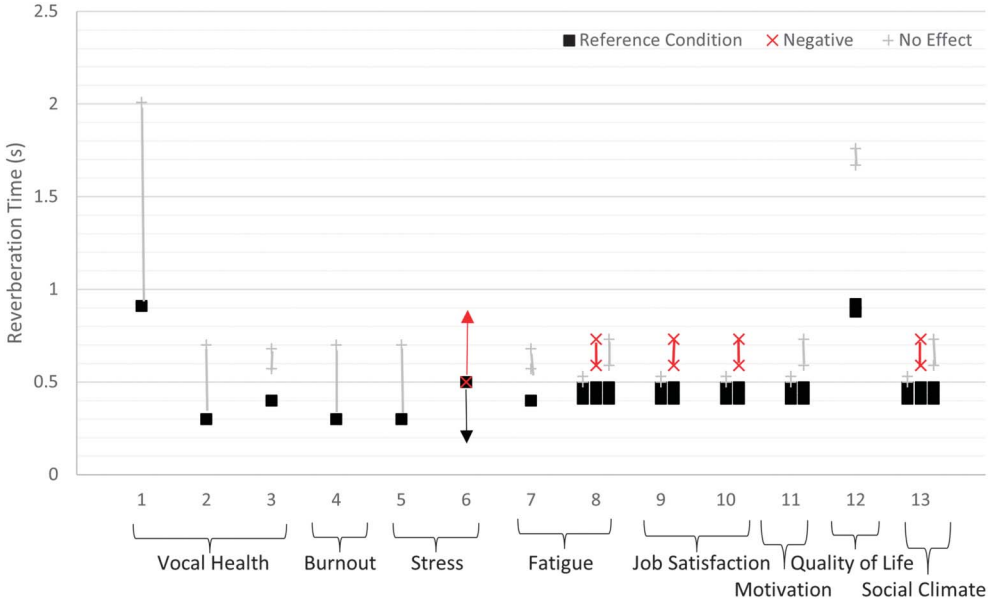
Figure 5. Effect of longer reverberation times (negative, no effect) on teachers' health and well-being for different health categories.



people may not have full insight into their health and well-being. Also, questionnaires and interviews are usually answered retrospectively so are reliant on how well the responder can remember the situation or how they were feeling. While these subjective measures may provide some helpful insights (especially if they are validated questionnaires), physiological measures can better provide objective measures at the time of the acoustic exposure. Of those studies in this review that did use physiological measures, five assessed vocal health, two assessed hearing, and one assessed heart rate. In addition, one study used cognitive tests. Hence, there is plenty of room for future research to include other physiological measures of health and well-being.

Second, more studies are needed that use objective acoustic data as well as self-report questionnaires. In this review, 18 studies used self-report as the type of assessment of the acoustic parameters, while 17 used objective measures. As mentioned in the previous paragraph, self-reports are subject to biases, so including objective acoustic measures

Figure 6. Effect of quantified reverberation time conditions (negative, no effect) on teachers' health and well-being for different reverberation times compared to the reference condition collated from reviewed articles. Lines represent when a range of reverberation times were studied. Arrows indicate when reverberation times above/below indicated level were investigated. 1 = Cutiva and Burdorf (2015); 2 = Karjalainen et al. (2020); 3 = Kristiansen et al. (2016); 4 = Karjalainen et al. (2020); 5 = Karjalainen et al. (2020); 6 = Tiesler and Oberdörster (2008); 7 = Kristiansen et al. (2016); 8 = Kristiansen et al. (2013); 9 = Kristiansen et al. (2013); 10 = Persson et al. (2013); 11 = Kristiansen et al. (2013); 12 = Levandoski and Zannin (2022); 13 = Persson et al. (2013).



is vital to understand the link between classroom acoustic conditions and teachers' health and well-being.

Third, more studies are needed assessing a range of acoustic variables in addition to noise and reverberation. In this review, 30 studies assessed the effect of noise and 15 studies assessed the effect of reverberation, but only four studies assessed the effect of number of students; two studies assessed the effect of clarity; and one study assessed the effect of EDT, definition, STI, and attenuation. Therefore, more research is needed on these latter parameters. More research is also needed to understand how the variables interact, for example, some reverberation can help teachers to project their voice, but too much adversely affects speech perception and exacerbates noise, particularly during group work (Bottalico et al., 2016; Klatte et al., 2010).

Finally, in interpreting these results, it is important to consider how individual differences may impact teachers' ability to cope in poor classroom acoustic conditions. In particular, this review brought to light the study by Tomek and Urhahne (2022) and the influence an individuals' coping type can have on their self-reported stress from noise. The authors found that correlations were significant for teachers with all coping types, but teachers of the risk types (Type A and burnout type) were more vulnerable to school noise than teachers of the healthy type. Therefore, future studies on the impact of classroom acoustic conditions on teachers' health and well-being should take into consideration personal factors such as coping type.

Future Research Needs

Taking together all of these limitations and gaps in the current research, what is needed is a large-scale study assessing health and well-being in teachers from classrooms with a wide range of different acoustic conditions, taking into account teachers' coping styles, using both self-report questionnaires and physiological/cognitive assessments of a range of health and well-being outcomes, with self-report and objective acoustic data of the noise levels and a range of room acoustics variables in different types of classrooms. This research will help us gain a better understanding of the acoustic conditions that are needed to optimize teachers' health and well-being in the classroom.

Limitations of Review

This review has several limitations such as having a limited search strategy, language bias, heterogeneity of included studies, and publication bias, which should be considered when interpreting these conclusions. The search strategy for this scoping review focused solely on the impact of classroom acoustic conditions on teachers' health and well-being. The review revealed that most of the research was on teachers' vocal health. However, additional literature using key words such as "dysphonia" may not have been picked up by the general search term of health and well-being. Not using this term may also explain why there were so few studies that used physiological measures. Future reviews that focus solely on the impact of classroom acoustic conditions on teachers' vocal health that include all relevant terms in the search strategy would be beneficial.

Conclusions

This scoping review found that the majority of results on the effect of classroom acoustic conditions on teachers' health and well-being showed that higher noise levels or a higher number of students have a negative effect on teachers' health and well-being (61% and 60%, respectively). Regarding longer reverberation times, 39% of results showed a negative effect. Most of the other results showed no effect of different acoustic conditions on teachers' health and well-being. The most common symptom studied was vocal health. Limitations and gaps in the reviewed literature were discussed, and future research to fill these gaps was proposed to help us gain a better understanding of the acoustic conditions that are needed to optimize teachers' health and well-being in the classroom.

Data Availability Statement

Data sharing is not applicable to this article as no data sets were generated or analyzed during the current study.

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References

American National Standards Institute. (2010). *ANSI/ASA S12.60-2010/Part 1 American national standard acoustical performance criteria, design requirements, and guidelines for schools, Part 1: Permanent schools*.

American Speech-Language-Hearing Association. (2005). *Acoustics in educational settings: Technical report*. https://doi.org/10.1044/policy.TR2005-00042

Astolfi, A., Puglisi, G. E., Prodi, N., Kang, J., Shtrepi, L., & Visentin, C. (2022). Editorial: Acoustics in the built environment: A challenge for improving the quality of life. *Frontiers in Built Environment, 8*. https://doi.org/10.3389/fbuil.022.887324

Atará-Piraquive, Á. P., Herrera-Guzmán, C. L., Hernández-Contreras, J. R., Rincón-Pinilla, M. P., Peña-Campagnoli, A. T., Florez-Lancheros, G. P., & Cantor-Cutiva, L. C. (2021). Effect of a workplace vocal health promotion program and working conditions on voice functioning of college professors. *Journal of Voice, 37*(6), P886–896. https://doi.org/10.1016/j.jvoice.2021.05.016

Australia/New Zealand Standard. (2016). *AS/NZS2107:2016, Acoustics—Recommended design sound levels and reverberation times for building interiors*.

Banks, R. E., Bottalico, P., & Hunter, E. J. (2018). The effect of classroom capacity on vocal fatigue as quantified by the vocal fatigue index. *Folia Phoniatrica et Logopaedica, 69*(3), 85–93. https://doi.org/10.1159/000484558

Berglund, B., & Lindvall, T. (1995). Community noise. *Archives of the Center for Sensory Research, 2*(1), 1–195. https://www.nonoise.org/library/whonoise/whonoise.htm

Berglund, B., Lindvall, T., & Schwela, D. (1999). New WHO guidelines for community noise. *Noise & Vibration Worldwide, 31*(4), 24–29. https://doi.org/10.1260/0957456001497535

Bernstorf, E. D., & Burk, K. W. (1996). Vocal integrity of elementary vocal music teachers: Personal and environmental factors. *Journal of Research in Music Education, 44*(4), 369–383. https://doi.org/10.2307/3345448

Bottalico, P., Graetzer, S., & Hunter, E. J. (2015). Effects of voice style, noise level, and acoustic feedback on objective and subjective voice evaluations. *The Journal of the Acoustical Society of America, 138*(6), EL498–EL503. https://doi.org/10.1121/1.4936643

Bottalico, P., Graetzer, S., & Hunter, E. J. (2016). Effect of reverberation time on vocal fatigue. *Proceedings of the International Conference on Speech Prosody* (pp. 494–497). https://doi.org/10.21437/speechprosody.2016-101

Bulunuz, N., Coskun Onan, B., & Bulunuz, M. (2021). Teachers' noise sensitivity and efforts to prevent noise pollution in school. *Eurasian Journal of Educational Research, 21*(26), 171–197. https://doi.org/10.14689/enad.26.8

Ciliska, D., Miccuci, S., Dobbins, M., & Thomas, B. H. (2010). *Quality assessment tool for quantitative studies*. Effective Public Health Practice Project.

Crandell, C. C., & Smaldino, J. J. (2000). Classroom acoustics for children with normal hearing and with hearing impairment. *Language, Speech, and Hearing Services in Schools, 31*(4), 362–370. https://doi.org/10.1044/0161-1461.3104.362

Cutiva, L. C. C., & Burdorf, A. (2015). Effects of noise and acoustics in schools on vocal health in teachers. *Noise & Health, 17*(74), Article 17. https://doi.org/10.4103/1463-1741.149569

Cutiva, L. C. C., & Burdorf, A. (2016). Work-related determinants of voice complaints among school workers: An eleven-month follow-up study. *American Journal of Speech-Language Pathology, 25*(4), 590–597. https://doi.org/10.1044/2016_AJSLP-14-0191

de Alcantara, M. A., de Medeiros, A. M., Claro, R. M., & Vieira, M. d. T. (2019). Determinants of teachers' work ability in basic education in Brazil: Educatel study, 2016. *Cadernos De Saude Publica, 35*(Suppl. 1), 1–12. https://doi.org/10.1590/0102-311X00179617

de Medeiros, A. M., Barreto, S. M., & Assunção, A. Á. (2008). Voice disorders (dysphonia) in public school female teachers working in Belo Horizonte: Prevalence and associated factors. *Journal of Voice, 22*(6), 676–687. https://doi.org/10.1016/j.jvoice.2007.03.008

Devadas, U., Bellur, R., & Maruthy, S. (2017). Prevalence and risk factors of voice problems among primary school teachers in India. *Journal of Voice, 31*(1), 117.e1–117.e10. https://doi.org/10.1016/j.jvoice.2016.03.006

Dodge, R., Daly, A. P., Huyton, J., & Sanders, L. D. (2012). The challenge of defining wellbeing. *International Journal of Well-being, 2*(3), 222–235. https://doi.org/10.5502/ijw.v2i3.4

Garnier, M., Ménard, L., & Alexandre, B. (2018). Hyper-articulation in Lombard speech: An active communicative strategy to enhance visible speech cues? *The Journal of the Acoustical Society of America, 144*(2), 1059–1074. https://doi.org/10.1121/1.5051321

Grebennikov, L., & Wiggins, M. (2006). Psychological effects of classroom noise on early childhood teachers. *The Australian Educational Researcher, 33*(3), 35–53. https://doi.org/10.1007/BF03216841

Hascher, T., & Waber, J. (2021). Teacher well-being: A systematic review of the research literature from the year 2000–2019. *Educational Research Review, 34,* Article 100411. https://doi.org/10.1016/j.edurev.2021.100411

Imms, W., Mahat, M., Byers, T., & Murphy, D. (2017). *Type and use of innovative learning environments in Australasian schools ILETC Survey No. 1*. Technical Report 1/2017. http://www.iletc.com.au/publications/reports

Karjalainen, S., Brännström, J. K., Christensson, J., Sahlén, B., & Lyberg-Åhlander, V. (2020). A pilot study on the relationship between primary-school teachers' well-being and the acoustics of their classrooms. *International Journal of Environmental Research and Public Health, 17*(6). https://doi.org/10.3390/ijerph17062083

Klatte, M., Lachmann, T., & Meis, M. (2010). Effects of noise and reverberation on speech perception and listening comprehension of children and adults in a classroom-like setting. *Noise and Health, 12*(49), 270–282. https://www.noiseandhealth.org/text.asp?2010/12/49/270/

Korn, G. P., Pontes, A. A. d. L., Abranches, D., & Pontes, P. A. d. L. (2015). Hoarseness and risk factors in university teachers. *Journal of Voice, 29*(4), 518.e21–518.e28. https://doi.org/10.1016/j.jvoice.2014.09.008

Kristiansen, J., Lund, S. P., Persson, R., Challi, R., Lindskov, J. M., Nielsen, P. M., & Toftum, J. (2016). The effects of acoustical refurbishment of classrooms on teachers' perceived noise exposure and noise-related health symptoms. *International Archives of Occupational and Environmental Health, 89*(2), 341–350. https://doi.org/10.1007/s00420-015-1077-3

Kristiansen, J., Lund, S. P., Persson, R., Shibuya, H., Nielsen, P. M., & Scholz, M. (2014). A study of classroom acoustics and school teachers' noise exposure, voice load and speaking time during teaching, and the effects on vocal and mental fatigue development. *International Archives of Occupational and Environmental Health, 87*(8), 851–860. https://doi.org/10.1007/s00420-014-0927-8

Kristiansen, J., Persson, R., Lund, S. P., Shibuya, H., & Nielsen, P. M. (2013). Effects of classroom acoustics and self-reported noise exposure on teachers' well-being. *Environment and Behavior, 45*(2), 283–300. https://doi.org/10.1177/0013916511429700

Levandoski, G., & Zannin, P. H. T. (2022). Quality of life and acoustic comfort in educational environments of Curitiba, Brazil. *Journal of Voice, 36*(3), 436.e9–436.e16. https://doi.org/10.1016/j.jvoice.2020.05.030

Lin, S., Lipton, E., Lu, Y., & Kielb, C. (2020). Are classroom thermal conditions, lighting, and acoustics related to teacher health symptoms? *Indoor Air, 30*(3), 544–552. https://doi.org/10.1111/ina.12640

Lombard, É. (1911). Le signe de l'élévation de la voix [The sign of the elevation of the voice]. *Annales Des Maladies de l'Oreille et Du Larynx, 37*(2), 101–109.

Lyberg-Åhlander, V., Rydell, R., Löfqvist, A., Pelegrin-García, D., & Brunskog, J. (2015). Part summary of the project "speakers" comfort': Teachers' voice use in teaching environments. *Building Acoustics, 22*(3–4), 209–224. https://doi.org/10.1260/1351-010X.22.3-4.209

Maia, E. G., Claro, R. M., & Assunção, A. Á. (2019). Múltiplas exposições ao Risco de faltar ao trabalho nas escolas da Educação Básica no Brasil [Multiple exposures to the risk of missing work in basic education schools in Brazil]. *Cadernos De Saude Publica, 35*(Suppl. 1), 1–13. https://doi.org/10.1590/0102-311X00166517

Mealings, K. T. (2016). Classroom acoustic conditions: Understanding what is suitable through a review of national and international standards, recommendations, and live classroom measurements. *2nd Australasian Acoustical Societies Conference, ACOUSTICS 2016* (Vol. 2). https://acoustics.asn.au/conference_proceedings/AASNZ2016/

Mealings, K. T. (2021). Acoustics and classrooms. In M. A. Peters & R. Heraud (Eds.), *Encyclopedia of educational innovation*. Springer. https://doi.org/10.1007/978-981-13-2262-4_200-2

Mealings, K. T. (2022a). A scoping review of the effect of classroom acoustic conditions on primary school children's numeracy performance and listening comprehension. *Acoustics Australia, 51*(1), 129–158. https://doi.org/10.1007/s40857-022-00284-3

Mealings, K. T. (2022b). A scoping review of the effects of classroom acoustic conditions on primary school children's mental well-being. *Building Acoustics, 29*(4), 529–542. https://doi.org/10.1177/1351010X221117899

Mealings, K. T. (2022c). A scoping review of the effects of classroom acoustic conditions on primary school children's physical health. *Acoustics Australia, 50*(3), 373–381. https://doi.org/10.1007/s40857-022-00271-8

Mealings, K. T. (2022d). Classroom acoustic conditions and primary school children's behaviour: A scoping review. *Building Acoustics, 29*(4), 543–558. https://doi.org/10.1177/1351010X221126680

Mealings, K. T. (2022e). Classroom acoustics and cognition: A review of the effects of noise and reverberation on primary school children's attention and memory. *Building Acoustics, 29*(3), 401–431. https://doi.org/10.1177/1351010X221104892

Mealings, K. T. (2022f). The effect of classroom acoustic conditions on literacy outcomes for children in primary school: A review. *Building Acoustics, 29*(1), 135–156. https://doi.org/10.1177/1351010X211057331

Mealings, K. T., Buchholz, J. M., Demuth, K., & Dillon, H. (2015). Investigating the acoustics of a sample of open plan and enclosed kindergarten classrooms in Australia. *Applied Acoustics, 100,* 95–105. https://doi.org/10.1016/j.apacoust.2015.07.009

Mealings, K. T., Demuth, K., Buchholz, J. M., & Dillon, H. (2015). An assessment of open plan and enclosed classroom listening environments for young children: Part 2. Teachers' questionnaires. *Journal of Educational, Pediatric & (Re)Habilitative Audiology, 21,* 20–38.

Minelli, G., Puglisi, G. E., & Astolfi, A. (2022). Acoustical parameters for learning in classroom: A review. *Building and Environment, 208*. https://doi.org/10.1016/j.buildenv.2021.108582

Moreno, M., Calvache, C., & Cantor-Cutiva, L. C. (2022). Systematic review of literature on prevalence of vocal fatigue among teachers. *Journal of Voice*. Advance online publication. https://doi.org/10.1016/j.jvoice.2022.07.029

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1), Article 143. https://doi.org/10.1186/s12874-018-0611-x

Murgia, S., Webster, J., Cutiva, L. C. C., & Bottalico, P. (2022). Systematic review of literature on speech intelligibility and classroom acoustics in elementary schools. *Language, Speech, and Hearing Services in Schools, 54*(1), 322–335. https://doi.org/10.1044/2022_lshss-21-00181

Novanta, G. G. R., Garavelli, S. L., & Sampaio, A. L. L. (2020). Is the level of noise in a school environment be harmful to the hearing of teachers? *International Archives of Otorhinolaryngology, 24*(4), e503–e507. https://doi.org/10.1055/s-0040-1702969

Nusseck, M., Spahn, C., Echternach, M., Immerz, A., & Richter, B. (2020). Vocal health, voice self-concept and quality of life in German school teachers. *Journal of Voice, 34*(3), 488.e29–488.e39. https://doi.org/10.1016/j.jvoice.2018.11.008

OECD. (2014). How much time do teachers spend teaching? In *Education at a glance: Highlights* (pp. 68–69). https://doi.org/10.1787/eag_highlights-2014-26-en

Pelegrín-García, D., Brunskog, J., & Rasmussen, B. (2014). Speaker-oriented classroom acoustics design guidelines in the context of current regulations in european countries. *Acta Acustica united with Acustica, 100*(6), 1073–1089. https://doi.org/10.3813/AAA.918787

Persson, R., Kristiansen, J., Lund, S. P., Shibuya, H., & Nielsen, P. M. (2013). Classroom acoustics and hearing ability as determinants for perceived social climate and intentions to stay at work. *Noise and Health, 15*(67), 446–453. https://doi.org/10.4103/1463-1741.121254

Phadke, K. V., Abo-Hasseba, A., Švec, J. G., & Geneid, A. (2019). Influence of noise resulting from the location and conditions of classrooms and schools in upper Egypt on teachers' voices. *Journal of Voice, 33*(5), 802.e1–802.e9. https://doi.org/10.1016/j.jvoice.2018.03.003

Pirilä, S., Pirilä, P., Ansamaa, T., Yliherva, A., Sonning, S., & Rantala, L. (2018). Relationship between activity noise, voice parameters, and voice symptoms among female teachers. *Folia Phoniatrica et Logopaedica, 69*(3), 94–102. https://doi.org/10.1159/000484204

Radwan, A., & Issa, M. H. (2017). An evaluation of indoor environmental quality and occupant well-being in Manitoba school buildings. *Journal of Green Building, 12*(1), 123–141. https://doi.org/10.3992/1552-6100.12.1.123

Rantala, L. M., Hakala, S. J., Holmqvist, S., & Sala, E. (2012). Connections between voice ergonomic risk factors and voice symptoms, voice handicap, and respiratory tract diseases. *Journal of Voice, 26*(6), 819.e13–819.e20. https://doi.org/10.1016/j.jvoice.2012.06.001

Rantala, L. M., & Sala, E. (2015). Effects of classroom acoustics on teachers' voices. *Building Acoustics, 22*(3–4), 243–258. https://doi.org/10.1260/1351-010X.22.3-4.243

Redel-Macías, M. D., Del Rio, C., Arezes, P., Aparicio-Martínez, P., & Cubero-Atienza, A. J. (2021). Environmental conditions of dance rooms and its impact on dance conservatories teachers' health (an Andalusian study). *International Journal of Environmental Research and Public Health, 18*(10). https://doi.org/10.3390/ijerph18105319

Redman, Y., Vercelli, C., Cantor-Cutiva, L. C., & Bottalico, P. (2022). Work-related communicative profile of voice teachers: Effects of classroom noise on voice and hearing abilities. *Journal of Voice, 36*(2), 291.e17–291.e31. https://doi.org/10.1016/j.jvoice.2020.05.021

Safe Work Australia. (2020). *Managing noise and preventing hearing loss at work: Code of practice*.

Sampaio, M. C., Borges Dos Reis, E. J. F., Carvalho, F. M., Porto, L. A., & Araújo, T. M. (2012). Vocal effort and voice

handicap among teachers. *Journal of Voice, 26*(6), 820.e15–820.e18. https://doi.org/10.1016/j.jvoice.2012.06.003

Schiller, I. S., Remacle, A., Durieux, N., & Morsomme, D. (2022). Effects of noise and a speaker's impaired voice quality on spoken language processing in school-aged children: A systematic review and meta-analysis. *Journal of Speech, Language, and Hearing Research, 65*(1), 169–199. https://doi.org/10.1044/2021_JSLHR-21-00183

Schomer, P. D., & Swenson, G. W. (2002). Electroacoustics. In *Reference data for engineers* (pp. 40-1–40-28). Elsevier. https://doi.org/10.1016/B978-075067291-7/50042-X

Shield, B. M., & Dockrell, J. E. (2004). External and internal noise surveys of London primary schools. *The Journal of the Acoustical Society of America, 115*(2), 730–738. https://doi.org/10.1121/1.1635837

Sierra-Polanco, T., Cantor-Cutiva, L. C., Hunter, E. J., & Bottalico, P. (2021). Changes of voice production in artificial acoustic environments. *Frontiers in Built Environment, 7*. https://doi.org/10.3389/fbuil.2021.666152

Simberg, S., Sala, E., Laine, A., & Rönnemaa, A.-M. (2001). A fast and easy screening method for voice disorders among teacher students. *Logopedics Phoniatrics Vocology, 26*(1), 10–16. https://doi.org/10.1080/140154301300109062

Stansfeld, S. A., Rasul, F. R., Head, J., & Singleton, N. (2011). Occupation and mental health in a national U.K. survey. *Social Psychiatry and Psychiatric Epidemiology, 46*(2), 101–110. https://doi.org/10.1007/s00127-009-0173-7

Tiesler, G., & Oberdörster, M. (2008). Noise—A stressor? Acoustic ergonomics of schools. *Acoustic Ergonomics of Schools, 15*(3), 249–261. https://doi.org/10.1260/135101008786348690

Tomek, R., & Urhahne, D. (2022). Relating teachers' coping styles to student noise and perceived stress. *Educational Psychology, 42*(3), 375–395. https://doi.org/10.1080/01443410.2022.2031892

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., & Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine, 169*(7), 467–473. https://doi.org/10.7326/M18-0850

Ubillos, S., Centeno, J., Ibañez, J., & Iraurgi, I. (2015). Protective and risk factors associated with voice strain among teachers in castile and Leon, Spain: Recommendations for voice training. *Journal of Voice, 29*(2), 261.e1–261.e12. https://doi.org/10.1016/j.jvoice.2014.08.005

van Houtte, E., Claeys, S., Wuyts, F., & Van Lierde, K. (2012). Voice disorders in teachers: Occupational risk factors and psycho-emotional factors. *Logopedics Phoniatrics Vocology, 37*(3), 107–116. https://doi.org/10.3109/14015439.2012.660499

Van Summers, W., Pisoni, D. B., Bernacki, R. H., Pedlow, R. I., & Stokes, M. A. (1988). Effects of noise on speech production: Acoustic and perceptual analyses. *Journal of the Acoustical Society of America, 84*(3), 917–928. https://doi.org/10.1121/1.396660

Whitlock, J. A. T., & Dodd, G. (2008). Speech intelligibility in classrooms: Specific acoustical needs for primary school children. *Building Acoustics, 15*(1), 35–47. https://doi.org/10.1260/135101008784050223

World Health Organization. (2018). *Environmental noise guidelines for the European region executive summary*. http://www.euro.who.int/__data/assets/pdf_file/0009/383922/noise-guidelines-exec-sum-eng.pdf