Noise Levels Among First, Second, and Third Grade Elementry School Classrooms In Hawaii

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This study examined background and octave band noise levels collected from a combination of 79 unoccupied urban public and private school classrooms in Hawai'i (island of Oahu). Noise measurements were obtained from first, second, and third grade classrooms and room characteristics were determined for each classroom tested. Measurements were obtained in decibels with the sound level meter weighting switch in "A" position (dBA) and octave band noise spectra were collected to determine Noise Criteria (NC) ratings. Results indicated mean noise levels of all classrooms were above the 30 dBA criterion recommended by the American Speech and Hearing Association (ASHA, 1995), the 20 dB NC rating recommended by the American Speech and Hearing Association (ASHA, 1995), and the 35 dBA criterion recommended by the American National Standards Institute (ANSI, 2002) for educational settings. These findings are discussed.

KEY WORDS: acoustics, background noise, classroom, elementary school, Hawai'i, noise criteria contour

It has been estimated that at least one-third of more than 80,000 schools in the United States are in need of extensive repair or replacement of at least one major environmental feature, which often includes acoustic modifications for improvements in noise control (General Accounting Office, 1995). The impact of these conditions has led professionals, parents, organizations, and agencies to advocate for improvements in classroom acoustics to ensure that all students—those with normal hearing as well as those with hearing impairment—optimize their learning experience within the classroom (Crandell, 1993; Crandell and Smaldino, 2000). In turn, policy makers, disability advocates, and others representing the educational needs of children are making a case that classroom design and classroom acoustics should be addressed as an accessibility feature under the Americans with Disabilities Act (Sorkin, 2000).

A position statement developed by the American Speech-Language and Hearing Association (ASHA) Subcommittee on Acoustics in Education Settings recommends three well-known guidelines: 1) unoccupied classroom noise level should not exceed 30 dBA or noise criteria (NC) 20 dB contour; 2) signal-to-noise ratio (SNR) at the student's ear should exceed a minimum of +15 dB; and 3) reverberation times should not exceed 0.4 seconds (ASHA, 1995). Since that time the recommendations on acoustics in education settings have been amended by the American National Standards Institute (ANSI) Committee on Noise, under the secretariat of the Acoustical Society of America (ASA), in collaboration with the United States Architectural and Transportation Barriers Compliance Board (U.S. Access Board). As a consequence of ANSI/ASA efforts, a new standard (ANSI/ASA S12.60, 2002) was established that recommends maximum limits for unoccupied classroom noise at 35 dBA (or 55 dBC) and reverberation times should not exceed 0.6 seconds.

Background noise level, reverberation time, and SNRs have each received scientific inquiry. A number of investigations have examined classroom acoustics across settings ranging from preschool/Head Start centers (Porter and Dancer, 1998), elementary and middle schools (Blake and Busby, 1994; Berg, Blair, and Benson, 1996; Johnson, Stein, Broadway, and Markwalter, 1997; Anderson, 2004; Flexer, 2004; Jamieson, Kranjc, Yu, and Hodgetts, 2004; Ruscetta, Arjmand, and Pratt, 2005) to classroom environments at the college level (Addison, Dancer, Montague, and Davis, 1999). The bulk of concern due to improper classroom acoustics has focused on noise levels that exist in elementary school environments. For example, a study conducted by Knecht, Nelson, Whitelaw, and Feth (2002) examined noise levels in 32 unoccupied elementary school classrooms divided among 3 different school districts (newer suburban, older urban and rural) in Ohio. The investigators determined noise levels across classrooms ranged from 34 dBA to 66 dBA and only four of the 32 classrooms were below the ANSI (S12.60, 2002) criterion of 35 dBA. Classrooms with the lowest background noise and reverberation times were those from the newer suburban district as opposed to those classrooms located in older urban and rural districts.

Many elementary school classrooms tend to have acoustic tile ceilings, carpeted floors, and windows that allow for full closure. The collective affect of these conditions tends to reduce ambient noise. However, structural components among classrooms where temperatures and weather conditions are stable year-round are slightly different. For example, jalousie windows are extremely common among classroom settings in tropical climates. Jalousie construction (Figure 1) consists of glass or wood louvers that slightly overlap one another to form the panes of a window. The louvers work as a single-unit to tilt open, permitting air flow. A series of jalousie windows can be opened for improved ventilation; however, this advantage also creates a disadvantage. When closed, each louver of a jalousie window rests against the louver below it, rarely making an air-tight seal to adequately attenuate sound. This component of classroom construction, where proper ventilation may supersede proper acoustics, makes for increased exposure to environmental noise.

Figure 1. Photograph of jalousie windows.

A review of the literature turned up only one published study that examined acoustic conditions of classrooms with similar architectural and climate patterns with Hawai‘i. In that study, Polich and Segovia (1999) measured acoustic conditions in 18 classroom settings among non-traditional (i.e., tropical) environments involving children with hearing-impairment in Nicaragua. Occupied and unoccupied classroom ambient noise levels were obtained as well as measurements across octave bands. Wall, ceiling, floor, and window composition of each classroom were also noted. Results revealed only two of the 18 classrooms met established Nicaraguan standards for unoccupied classroom noise levels of less than 40 dBA and none of the classrooms met the recommended occupied noise level of less than 50 dBA.

Previous studies have examined classroom acoustics ranging from pre-school to college environments as well as in classrooms that exist in urban versus rural areas, yet it is somewhat surprising that additional data on acoustic conditions of classrooms in non-traditional settings, by grade level, or school type (i.e., public versus private) are limited. Given the findings from previous investigations, and those focused on unoccupied noise characteristics taken from elementary school classrooms in particular, the impetus for the present study sought to examine and describe acoustic conditions among elementary school settings in Hawai’i by 1) measuring background noise levels of unoccupied public and private first, second, and third grade classrooms and 2) measuring octave band noise spectra within each setting to determine NC ratings, a single number index commonly used to describe maximum allowable noise in a given space.

METHOD

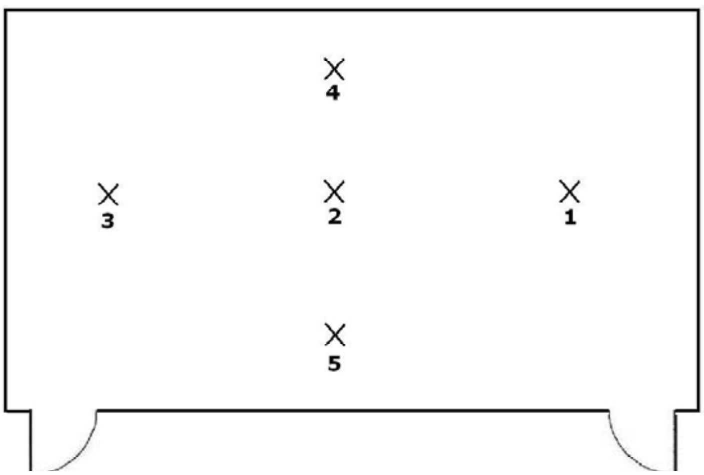
<u>Elementary School Settings</u>

A combination of urban public and private schools were randomly selected in Hawai‘i (island of Oahu). Attempts were made to obtain noise data from unoccupied first, second, and third grade classrooms at each school as well as document structural components (e.g., wall, ceiling, floor, window) and physical dimensions (in cubic feet) of each classroom. A total of 90 classrooms were targeted for evaluation.

<u>Equipment and Procedures</u>

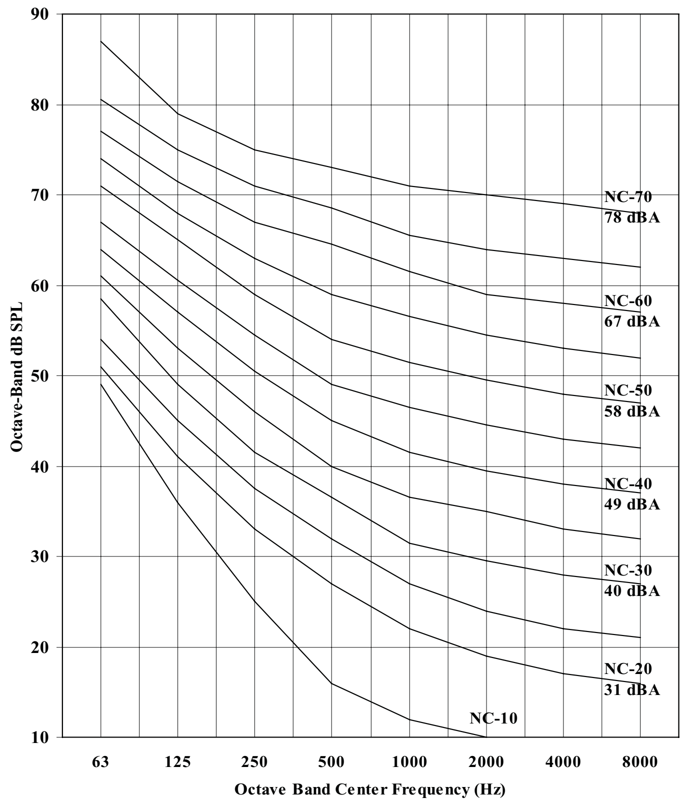
A Quest (Model 1800) precision integrating sound level meter (SLM) with an octave-band (Model OB-100) filter was used to obtain all noise measurements. The handheld Quest SLM has a digital liquid crystal and bar graph display, provides measurements across a wide variety of formats, and meets ANSI standards for Type 1 precision. The Quest SLM has a “run” feature that allows for real-time accumulation and storage of data for subsequent analysis. Noise measurements were obtained in decibels with the SLM weighting switch in the “A” position (dBA), which replicates the frequency sensitivity of the human ear by filtering out low-frequency noise components. The A-weighting scale also serves to predict the damage risk to the ear. Equipment calibration was conducted before and after each measurement was obtained. Calibration included a battery check and a signal output check that follows manufacturer guidelines. Noise samples were taken at five separate locations (Figure 2) of each classroom; measurement intervals of at least 30 seconds were made at each location over a 3-minute period. Within classroom measures were then averaged to represent the overall noise level of the classroom itself, a measurement technique supported by practice patterns in the literature (Polich and Segovia 1999; Knecht et al., 2002). To control for extraneous noise effects, all air conditioning units and/or fans that were present in classrooms were turned off. All noise levels were obtained over a three-month period prior to the start of the academic school year. Emphasis was placed on collecting noise measurements during school meeting times and classrooms within the same school were measured on the same day. All classrooms were arranged as they would have been for students and remained untouched during acquisition of measures.

Figure 2. Schematic illustration of the five locations used for obtaining noise samples from each classroom.



Octave band measures were collected immediately following compilation of background noise measures. Noise criteria ratings make use of octave band spectra as a means of evaluating sound in a given space. The NC rating employs a tangency method to compare octave band sound pressure level spectra to standard NC contours. Standard NC contours, first described by Beranek (1957), take into account the equal loudness contours of Fletcher and Munson (1933) to accurately reflect the listening experience. The lowest NC contour not exceeded by the plotted noise is the NC rating of the noise in that environment. Figure 3 illustrates a layout of NC contour curves.

Figure 3. Sample layout of noise criteria contour curves.



Although ASHA (1995) recommends octave band noise spectra of unoccupied classrooms to exist at or below the NC-20 contour, an acoustical analysis of classroom settings conducted by Darby (1992) revealed that octave band noise spectra should not exceed the NC-35 contour for unoccupied classrooms in Hawai‘i. This NC rating equates to a background noise level of 44 dBA for unoccupied classroom noise. Similar NC standards of classrooms in other non-traditional environments (Polich and Segovia, 1999) are unavailable.

Statistical Evaluation

Once the data were collected, all noise and octave band measurements were extracted from the Quest SLM, transferred to computer spreadsheets in a comma-delimited format, and analyzed with SAS (version 8.2, 2001) software. Analysis of variance (ANOVA) tests were conducted to detect statistically significant noise effects due to grade level (1st, 2nd, 3rd) and school type (public, private). Where applicable, p-values <.05 were considered as statistically significant.

RESULTS

From 90 possible classroom settings, data were collected from 79 classrooms (67 public, 12 private). The 11 classrooms excluded from inquiry were all from private school settings; eight classrooms were not included due to incomplete measures and data from three classrooms could not be obtained due to disinterest in participating in the study on behalf of school personnel. Classrooms contained in the sample were predominantly composed of concrete/brick walls (73.4%), acoustic tile ceilings (65.8%), tile floors (51.9%), jalousie windows (70.9%), and no air conditioning (86.1%) (Table 1).

Table 1. Summary of classroom characteristics (N = 79).

Variable	n	%	Mean	SD	Range
Physical Dimension (cubic feet)			7,693	1,466	4,566 – 13,104
Classroom by School Type					
Public	67	84.8			
Private	12	15.2			
Classroom by Grade Level					
First	33	41.8			
Second	30	37.9			
Third	16	20.3			
Wall Components					
Concrete/Brick	58	73.4			
Drywall	21	26.6			
Ceiling Components					
Acoustic Tile	52	65.8			
Concrete and Tile	22	27.8			
Wood	5	6.4			
Floor Components					
Tile	41	51.9			
Carpet	33	41.8			
Carpet and Tile	5	6.3			
Window Components					
Jalousie	56	70.9			
Glass Pane	23	29.1			
Air Conditioning					
No	68	86.1			
Yes	11	13.9			

Mean background noise levels for all classrooms (N=79) was 51.2 dBA (SD = 6.1; range = 37.9 dBA to 69.7 dBA). Likewise, mean background noise levels were 51.9 dBA (SD = 5.6), 51.1 dBA (SD = 6.4), and 49.8 dBA (SD = 6.6) for first, second, and third grade classrooms respectively (Table 2). The ANOVA tests determined differences in background noise levels due to grade level were not statistically significant (F=0.35; p=0.70).

Table 2. Background noise levels of classroom environments (*N* = 79).

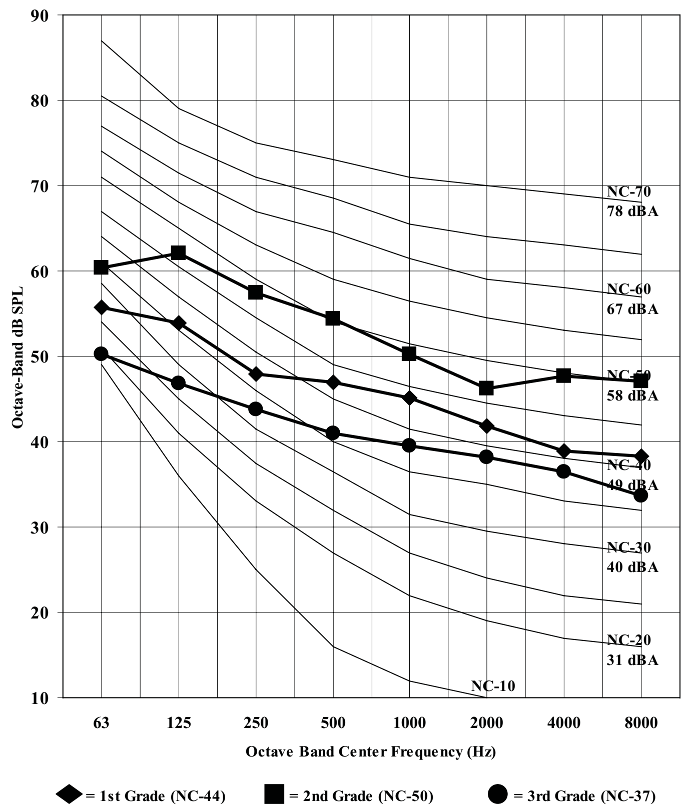
Variable	n	Mean	SD	Range
Classroom by Grade Level				
First	33	51.9	5.6	40.5 – 69.7
Second	30	51.1	6.4	38.3 – 67.7
Third	16	49.8	6.6	37.9 – 64.6
Classroom by School Type				
Public	67	52.1	5.8	38.3 – 69.7
Private	12	46.6	6.1	37.9 – 55.2

Background noise measures in dBA.

Because differences in background noise levels due to grade level were not statistically significant, the data were collapsed across grades to examine school type effects. Table 2 shows mean ambient noise levels for public (n = 67) and private (n = 12) school classrooms. Mean unoccupied background noise levels were 52.1 dBA (SD = 5.8) for public school classrooms and 46.6 dBA (SD = 6.1) for private classrooms. Differences in background noise levels due to school type were not statistically significant (F=0.50; p=0.48). Collectively, the trend shown by these findings indicates that none of the mean unoccupied background noise levels among classrooms met the 30 dBA criterion recommended by ASHA (1995) or the 35 dBA criterion recommended by ANSI (2002) for educational settings.

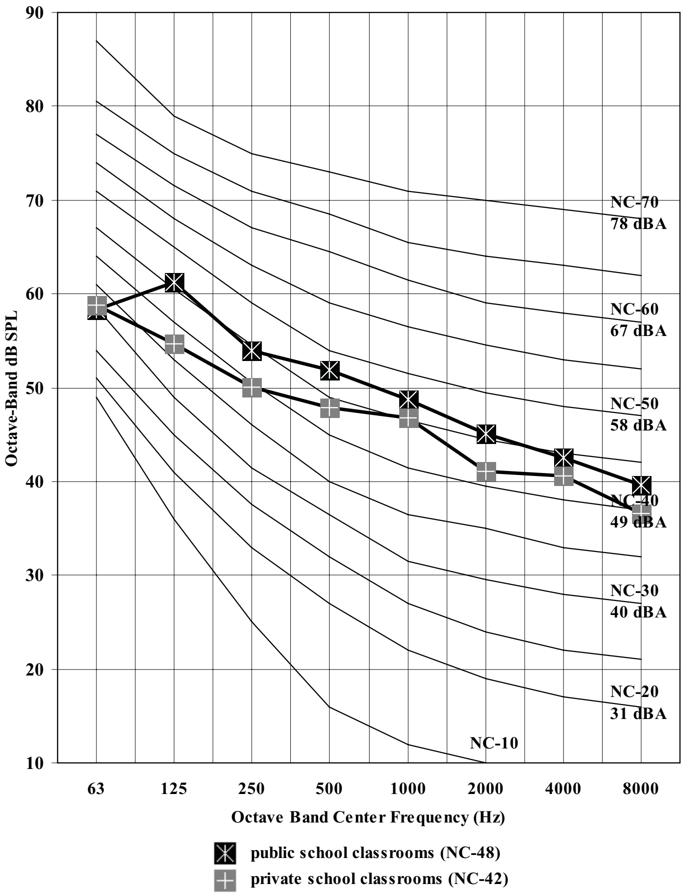
Figure 4 displays standard contour curves superimposed with mean NC curves plotted by grade level. The NC contour of second grade classrooms (NC-50 rating) exceeded NC contours of first grade (NC-44 rating) and third grade classrooms (NC-37 rating).

Figure 4. Noise criteria contours for background noise levels in first (n=33), second (n=30) and third (n=16) grade classrooms.



Mean octave band data also were collapsed across grade level to examine school type (Figure 5). The NC contour of public school classrooms (NC-48 rating) exceeded the NC contour of private classrooms (NC-42 rating). In each case, none of the classrooms met the NC ratings criteria (ASHA, 1995; Darby, 1992).

Figure 5. Noise criteria contours for background noise levels in public (n=67) and private (n=12) school classrooms.



DISCUSSION

Acoustics serve as a contributor to a child's academic success and/or failure, and data that depict poor classroom acoustics has been abundantly documented. The majority of prior studies (Johnson, Stein, Broadway, and Markwalter, 1997; Jamieson, Kranjc, Yu, and Hodgetts, 2004; Ruscetta, Arjmand, and Pratt, 2005; Knecht, Nelson, Whitelaw, and Feth, 2002; Polich and Segovia, 1999) provide data to indicate unoccupied classroom noise levels have routinely not met ASHA (1995) or ANSI (2002) recommendations. Unoccupied noise levels for classrooms in this study are consistent with noise measurements determined by other investigators, and findings from the present study lend further support to the notion of inadequate classroom acoustics among first, second and third grade elementary school classrooms in Hawai'i. The percentage of public (84.8%) and private (15.2%) school classrooms in our study closely mirror the current educational system in Hawai'i, where approximately one in five students attend private school (Heritage Foundation, 2004). The logical impact of these acoustic conditions on a child's ability to listen and learn in the ethnically diverse culture of Hawai'i—especially involving younger children at the beginning of their educational experience, children with hearing impairment, children with learning difficulties, or children learning through a second language—parallel the adverse effects found in other studies (Bess, 1985; Blake and Busby, 1994; Berg, Blair, and Benson, 1996; Anderson, 2004; Flexer, 2004; Nelson, Kohnert, Sabur, and Shaw, 2005).

Despite the lack of statistical significance due to grade level (F=0.35; p=0.70) or school type (F=0.50; p=0.48), there was a noticeable difference of approximately 6 dB between public (52.1 dBA) and private (46.6 dBA) school classrooms. This difference most likely occurred due to differing structural components. Several private school classrooms were equipped with glass pane windows and air conditioning while several public school classrooms were equipped with jalousie windows and no air conditioning. The NC contours due to grade level and school type also exceeded the NC-20 contour advocated by ASHA (1995) as well as the NC-35 contour for educational settings in Hawai'i. The only contour curve within reach of the NC-35 spectrum rating advocated by Darby (1992) was found among third grade classrooms (NC-37).

The usefulness of determining noise levels, NC contours, and NC ratings allow for implementing engineering and administrative controls to mitigate noise levels at their source, along its path, and at the receiver. A combination of acoustic improvements at each point can often produce noise reduction. For example, the most common structural component found lacking in a majority (86.1%, see Table 1) of the 79 classrooms in this study was air conditioning. Because of this trend the bulk of classrooms were equipped with jalousie windows (70.9%, see Table 1) for cooling and ventilation. The state of Hawai'i lies within a path of trade winds that prevail throughout the year, which provides natural ventilation to many school buildings. Jalousie windows are used to take advantage of this temperate climate and weather condition. Suggested engineering controls to improve acoustics would be to retrofit elementary classrooms in Hawai'i with windows that allow for full closure, install wall mounted air conditioning units, or ceiling fans, but these state-wide modifications are unrealistic because they would be too expensive to justify.

Large area rugs and tennis balls serve as alternate engineering controls to decrease sliding chair (i.e., source) noise in classrooms that do not have carpeted floors. Cutting an "X" pattern in 4 tennis balls just large enough to insert the metal legs of each chair within the classroom completes the task. There are many schools that already use tennis balls as a means of noise control, but it should be noted that issues have been raised regarding the suitability of tennis balls as a noise deterrent. A recent assessment by the Massachusetts Department of Public Health (2003) determined that tennis balls are made with a rubber latex bladder, which becomes abraded over time when used as a chair leg pad. Constant wearing of tennis balls on sliding chairs may introduce latex dust into a classroom environment and can become a respiratory irritant. Because of this potential effect, the National Institute for Occupational Safety and Health (NIOSH, 1997) recommends that use of materials containing latex is limited in buildings to reduce the likelihood of symptoms in latex-sensitive individuals. Conversely, administrative controls to improve listening conditions at the receiver can be completed with the utilization of personal FM or sound field amplification systems (Crandell, 1993; Crandell and Smaldino, 2000) along with recommending to school administrators the scheduling of all lawn and landscape maintenance procedures to occur either before or after school.

Data contained in this study describe acoustic conditions of elementary school classrooms in Hawai‘i, but these findings are limited because they shed light on only 1 of the 3 guidelines on acoustics in education settings (i.e., unoccupied classroom noise level/noise criteria ratings) recommended by ASHA (1995). Signal-to-noise ratios (SNRs), reverberation times, as well as occupied classroom noise levels by grade or school type remain uncertain because these acoustical components were not investigated. This circumstance is currently being considered for further inquiry. However, it seems reasonable to suggest that the logical pattern of acoustic conditions determined thus far will likely produce SNRs, reverberation times, and occupied classroom noise levels that may also exceed ASHA (1995) and ANSI (S12.60, 2002) guidelines. More studies along these lines that identify classroom acoustics, determine the impact of these conditions on speech perception skill, measure the effects of implementing engineering and administrative controls, and measure grade level and school type effects are in dire need.

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