The Classroom Listening Environment in the Early Grades

Le milieu d'écoute en salle de classe au premier cycle du primaire

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Abstract

Classroom acoustics contribute to a student's ability to hear, understand and learn in the classroom. The purpose of this study was to investigate selected components of the classroom listening environment in the early grades and to make recommendations for improving classroom listening. This study of 60 kindergarten to grade 3 classrooms investigated: 1) hearing status of students; 2) the noise level in classrooms; 3) classroom communication with and without sound field amplification; and 4) perceptions of teachers and students who used sound field amplification. Of those who participated in the hearing screenings (n=947), 71% to 88% met the criteria established in this study for adequate hearing levels. Acoustical quality of 26 classrooms indicated that only 31% of the classrooms met the recommended standard. Observation of communicative interactions in 31 amplified and 29 unamplified classrooms and interviews with teachers and students found that students focused better and exhibited fewer distracting communicative behaviours when they could hear the teacher clearly. School personnel need to be aware of the many components involved in creating optimal classroom listening environments including characteristics of the students, room acoustics, and benefits of using sound field amplification.

Abrégé

L'acoustique en salle de classe contribue à la capacité d'un élève à entendre la parole, à la comprendre et à apprendre. Cette étude visait à examiner certaines composantes du milieu d'écoute dans des salles de classe du premier cycle du primaire, ainsi qu'à présenter des recommandations pour améliorer l'écoute en salle de classe. Nous avons recruté 60 salles de classe de la maternelle à la troisième année pour examiner : 1) le niveau d'acuité auditive des élèves; 2) le niveau de bruit dans les salles de classe; 3) la communication dans les salles de classe avec et sans amplification du champ acoustique; 4) la perception des enseignants et des élèves dans les classes où l'amplification était utilisée. Parmi les élèves qui ont participé au dépistage de l'audition (n=947), 71 % à 88 % remplissaient les critères établis d'un niveau d'audition adéquat aux fins de cette étude. La mesure de la qualité acoustique de 26 salles de classe a démontré que seulement 31 % d'entre elles répondaient aux normes recommandées. Grâce à l'observation des interactions de communication dans 31 salles de classe avec amplification et 29 salles de classe sans amplification, de même qu'à des entrevues auprès des enseignants et des élèves, nous avons déterminé que les élèves avaient une meilleure attention et concentration et avaient moins de comportements de communication distrayants quand ils entendaient plus clairement l'enseignante. Le personnel travaillant dans les écoles doit connaître les nombreuses composantes qui favorisent un environnement d'écoute optimal en salle de classe, y compris les caractéristiques des élèves, l'acoustique de la salle et les avantages liés à l'utilisation de l'amplification du champ acoustique.

INTRODUCTION

Classroom listening conditions have a significant effect on students' academic success because learning is highly dependent on clearly hearing the messages being communicated (Edwards, 2005; Flexer, 2005). In an ideal classroom, words can be heard and understood by the students with little or no effort. Being able to focus on speech sounds is fundamental for learning the phonology of language, which underlies learning to read and write (Nelson, Kohnert, Sabur, & Shaw, 2005). Teachers who must raise their voices in order to be heard are unable to provide clear signals across the full range of speech sounds. As Boothroyd (2005) explains, a raised voice increases audibility, but not intelligibility of speech. A loud voice enhances the vowels, but may obscure the consonants where most of the meaning is carried (Flexer, 2005). Sound field amplification has been used to help improve the classroom listening environment by enhancing the voice of the person speaking and evenly distributing the speech signal throughout the room. Classroom acoustics, student characteristics, and sound field amplification all contribute to the listening environment and are discussed in more depth below.

Classroom acoustics

A number of features within classrooms, as well as external noise sources, influence classroom acoustics. Noise sources may include background noise from heating, ventilation and air conditioning (HVAC) systems or electronic equipment in the room, collaborative groups in the classroom, and noise in the hallways or outside the windows (Crandell, Smaldino, & Kreisman, 2004; Nelson & Soli, 2000). In addition to noise, the degree to which surfaces absorb, reflect, or reverberate sound (Smaldino & Crandell, 2000; Smaldino, Doggett, & Thunder, 2004) and the natural loss of the teacher's speech signal as it travels over distance (Crandell, et al., 2004; Nelson & Soli, 2000) affect classroom acoustics.

Effective communication in the classroom largely depends on having a speech signal that is intelligible over the background noise. Sato & Bradley (2008) noted that a desirable listening environment for young students is created with a +15 dB signal-to-noise ratio (S/N). While there are no national building code standards in Canada for classroom acoustics, national standards have been developed in a number of other countries (Shield & Dockrell, 2003). The American National Standards Institute (ANSI) recommends 35 dB for an acceptable classroom noise level (Acoustical Society of America, 2002). When this standard is met, a S/N of at least +15 dB can be achieved provided that the speech signal is a minimum of 50 dB (Acoustical Society of America, 2002). In most classrooms, background noise levels can be a significant problem. It has long been recognized in the United States that the acoustic environment in occupied classrooms is greater than 35 dBA (American Speech-Language-Hearing Association, 2005). In fact, Nelson et al. (2005) estimated that many occupied classrooms have noise levels of 70 dBA or higher, which would result in a S/N of 0 or -5 dB for an average speaker.

ANSI in the S12.60 standard also recommends a maximum of 0.6 seconds as a standard reverberation time (RT) for classrooms (Acoustical Society of America, 2002). RT refers to the amount of time required for a signal to decrease 60 dB below its initial level (Crandell et al, 2004). Picard and Bradley (2001) reported results from seven studies that measured RTs in classrooms and found values that ranged mainly from 0.4 to 1.2 seconds. In addition, Seep, Glosemeyer, Hulce, Linn, & Aytar (2000) noted that many American classrooms have RTs of 1 second or more. Although Picard and Bradley recognized that both RTs and noise levels were often too high in classrooms, noise levels exceed recommendations to a greater degree than do RTs and, therefore, interfere more with speech recognition.

Student characteristics

It has been shown that speech perception may be adversely affected in classrooms with poor acoustics (Boothroyd, 2004; Crandell, Kreisman, Smaldino, & Kreisman, 2004). Being able to clearly understand speech in the classroom environment is important for early literacy learning, which potentially impacts later academic performance (Nelson, et al., 2005). Palmer (1998) explained that students who are able to hear the signal clearly are less fatigued, leading to better educational outcomes.

While it is commonly recognized that students with sensorineural hearing loss have difficulty with speech recognition in noisy or reverberant environments, it is less well known that other student characteristics also affect the ability to understand speech in the classroom (Crandell, Smaldino, & Flexer, 2005; Nelson & Soli, 2000). These characteristics include conductive hearing loss, temporary hearing loss due to otitis media, articulation disorder, language disorder, auditory processing deficit, learning disabilities, attentional deficits, developmental delays, the age of the student, and the student's level of familiarity with the language of the classroom (Bennetts & Flynn, 2002; Cornwell & Evans, 2001; Crandell, Smaldino, & Flexer, 2005; DiSarno, Schowalter, & Grassa, 2002; Flexer & Long, 2003; Flexer, Millin, & Brown, 1990).

Crandell et al. (2005) stated that recurrent bouts of otitis media with effusion (OME) have been associated with speech, language, intellectual, and attentional problems. Hearing screenings are needed to identify students who have sensorineural hearing loss as well as those who have middle ear problems (Yockel, 2002). Flexer, Richards, Buie, and Brandy (1994) found a high incidence of minimal hearing loss in their study of young children who were tested at four different times of the year. One fourth to one third of their 282 kindergarten and grade 1 students had reduced hearing with the results varying by season. Otitis media and associated minimal hearing loss have been reported to be increasing among school aged children and even slight hearing loss has been related to deficits in vocabulary, reading, and other academics as well as reduced incidental learning (Nelson, 1999).

In a large study in the United States, air conduction thresholds at 500 to 8000 Hz were measured in over 6000 students aged 6 to 19 years (Niskar, Kieszak, Holmes, Esteban, Rubin, & Brody, 1998). The prevalence of hearing loss, defined in this study as threshold values of at least 16 dB, was 14.9%. These researchers concluded that screening of both the high and low frequencies is needed to detect hearing loss in school-aged students. Yockel (2002) performed pure-tone audiometric screenings with 141 students aged 5 to 8 years from special and regular educational programs. For those who did not hear every tone at their criteria of 25 dB, a hearing threshold test was done and for those who did not pass, middle ear testing was conducted. A total of 21% of the students failed either the pure-tone or middle ear testing. With the middle ear testing, 10 students with OME were identified who otherwise would have been overlooked on the pure-tone testing alone. In another study by Serpanos and Jarmel (2007), 5% of a sample of 3 to 5 year old children did not pass a pure-tone screening at their criteria of 20 dB using levels of 1000, 2000, 3000, and 4000 Hz. Given the importance of good hearing for learning in the classroom, early identification of hearing problems is vital.

Adults have more developed auditory systems than children and, therefore, may not appreciate the negative effects of poor classroom acoustics on young students (Bradley & Sato, 2004). Children younger than 13 to15 years do not have mature hearing systems and their ability to focus in noisy surroundings is less well developed than that of adults (Anderson, 2004; Boothroyd, 2004; Crandell & Smaldino, 2000; Flexer, 2005). Furthermore, due to fewer life experiences, young children have less extensive vocabularies to help them fill in the gaps of missed information (Flexer, 2005; Seep et al., 2000). Bradley and Sato (2004) demonstrated that young students require a higher signal-to-noise ratio (S/N) for speech recognition than young adults. Speech recognition was tested using the Word Intelligibility by Picture Identification (WIPI) at two different S/N values for grade 1 and three values for grades 3 and 6. In this test, each word is presented aurally and students are asked to identify the correct picture. The results included intelligibility scores over a range of S/N from -15 to +30 dB. Students in grade 1 required +15.5 dB S/N to achieve a mean score of 95% correct in the WIPI speech recognition task, while students in grade 3 required +12.5 dB S/N, and those in grade 6 required +8.5 dB S/N for these same results. With a higher S/N of +25 dB to +30 dB, the students in grade 1 and grade 3 had a mean score of 98%, while those in grade 6 scored on average almost 100% on this speech recognition task.

The need for good acoustics is especially important for students who are learning in a second language because they cannot rely on previous linguistic experience and must depend more heavily on hearing the spoken messages accurately (Nelson & Soli, 2000). Nelson et al. (2005) tested grade 2 students, who were either non-native English speakers or native English speakers, using a picture-word identification task in quiet and noise conditions. They found that noise had a stronger negative impact on word recognition performance for the non-native English speakers. In another study with 8 to 10 year olds who were either English second language learners or native English speakers, sentence perception was tested across varying noise conditions (Crandell & Smaldino, 1996). The results indicated that students learning in a second language had more difficulty perceiving speech in noise than did native speakers and this effect increased with higher noise levels. Recognition of speech in noisy or reverberant environments has also been found to be more difficult for non-native adults than for adults listening in their native language (Bradlow & Alexander, 2007). Further, Mayo, Florentine, and Buus (1997) found that adults who learn a second language earlier in life are better able to perceive speech in noise than those who learn later.

Sound field amplification

Reducing barriers to classroom listening is essential for improving the learning environment. The room acoustics and student characteristics contribute to the ability to hear and understand in the classroom. In addition, researchers have found that enhancing the classroom listening environment through sound field amplification has positive effects on students' learning (Crandell et al., 2005; DiSarno et al, 2002; Eriks-Brophy & Ayukawa, 2000; Massie, Theodoros, Bryne, McPherson, & Smaldino, 1999). Sound field amplification technology is a method for enhancing the vocal signal above the background noise found in typical classrooms. Amplification allows teachers to speak in conversational tones and can reduce their voice strain (Jónsdottir, Laukkanen, & Siikki, 2003; Sapienza, Crandell, & Curtis, 1999).

Sound field technology includes a wireless microphone with one or more loudspeakers which allow the voice of the person speaking to be enhanced. The speech signal is evenly distributed around the room and the message is more clearly heard over the background noise. The use of a pass-around handheld microphone for individual students can also help them to hear their peers more clearly when discussion is part of the learning activity.

PURPOSE

The purpose of this study was to investigate selected components of classroom listening environments in the early grades with a Canadian sample and to make recommendations for improving listening and, ultimately, learning in the classroom. Specifically, this study measured: 1) the hearing status of kindergarten to grade 3 students; 2) the noise level in some of their classrooms; 3) classroom communication with and without sound field amplification; and 4) perceptions of teachers and students who used sound field amplification.

Addressing students' hearing status and deficits in room acoustics are the first steps towards removing the barriers to optimal classroom listening. Sound field amplification can also help to improve the listening environment by enhancing the voice of the person speaking. The present study measured the effects of introducing this technology into the classroom environment by focusing on students' responses to teachers' communication with and without sound field amplification and the perceptions of teachers and students about this technology.

METHOD

Participants

This study involved eight schools across three school districts in an eastern Canadian province. The location of the three districts was selected by the Department of Education. The districts represented geographically separate regions of the province and included an urban and rural mix. The Directors of Student Services within each district provided the researchers with information to enable matching of schools on the number of students registered and the type of program(s) offered (English and French Immersion). The Directors of Student Services identified which schools were to be provided with sound field amplification systems.

The number of students in the participating classes by school district and type of program is outlined in Table 1. A total of 947 students participated in the hearing screenings. Sound field systems were installed in 31 classes (n=610 students), which comprised the amplified group, and not in 29 classes (n=552 students), which comprised the unamplified group.

Table 1

Number of Students and Classes by Grade and Program

Grade	Program	Amplified		Unamplified	
		Classes	Students	Classes	Students
Kindergarten	English	7	148	7	143
Grade 1	English	5	83	4	60
Grade 1	French Immersion	3	59	3	59
Grade 2	English	5	90	5	82
Grade 2	French Immersion	3	60	3	50
Grade 3	English	5	109	4	100
Grade 3	French Immersion	3	61	3	58
Kindergarten to Grade 3	English and French Immersion	31	610	29	552
Kindergarten to Grade 3	English	22	430	20	385
Grade 1 to Grade 3	French Immersion	9	180	9	167

Note: French Immersion program is not available in Kindergarten.

Procedure

The study took place in the winter and spring months of the same school year and involved four components: (a) hearing screenings, (b) classroom noise measurements, (c) classroom observations, and (d) participant interviews. Each classroom in the amplified group was provided with a Phonic Ear frontrow™ pro infrared sound field system, four mounted speakers, a wireless pendant microphone, and one handheld wireless microphone. There were variations in the way the sound systems were installed and the length of time required to install them since each school district made its own arrangements. Teachers received basic instruction on the technology from either an audiologist or the sound system vendor. Since a standard in-service training package was not available, the content of the training may have varied.

Parents or guardians of students submitted a written permission form for their child's participation in the classroom observations and interviews. A second written permission form was required for the hearing screening. Teachers also submitted a written permission form for their participation. Of the 1162 students in the participating classes, parents of 87% of the students (n=1011) gave permission for their child to be observed and parents of 88% of the students (n=1023) gave permission to have their child's hearing screened. Of the 139 parents who did not consent to a hearing screening, four identified that their child had a hearing loss, two identified that their child had special needs, and the remaining 133 did not give a reason for their decision.

Hearing screenings

Hearing screenings were conducted by the first author, a speech-language pathologist (SLP), using a GSI 17 Grason-Stadler 17 portable screening audiometer. An audiologist provided assistance with screening students in three of the schools using a Model MD-IP M.D. audiometer. The SLP and audiologist were certified by the Canadian Association of Speech-Language Pathologists and Audiologists. Both audiometers were calibrated in a hospital audiology department prior to the study. Operational checks were made to ensure their proper functioning prior to each school visit. Screenings took place in quiet rooms that were made available by the school administrators such as conference or library spaces. The SLP or audiologist monitored the acoustical conditions to ensure that they were appropriate for conducting the screenings. On occasion, the ambient noise level was subjectively judged to be high enough to interfere with testing and an alternate location was used.

Instruction was provided by the SLP or the audiologist to an individual or small group of up to six students as the room size and attention span of the children permitted. Instruction included placement of the headphones and practice responding by raising a hand to tones presented by the examiner without using the headphones. For a small number of students, who could not reliably raise their hands when hearing the tone, an alternate procedure was utilized. This involved teaching the students to respond to the sound by releasing an item into a container each time they heard a sound.

Students were screened using the guidelines established by the New Brunswick Association of Speech-Language Pathologists and Audiologists (1988). According to Niskar et al. (1998), the low frequency screening level of 500 Hz, while often not included in standard school screenings, should be performed. Screening levels were 500 Hz (25 dB), 1000 Hz (20 dB), 2000 Hz (20 dB), and 4000 Hz (20 dB). Students who responded to all of these frequencies were considered to have passed or met the criteria for adequate hearing. If the child failed to respond to one or more of the frequencies tested, the child was identified as needing to be rechecked or referred for follow-up. Of the total 1023 participants with parental consent for hearing screening, 93% (n=947) were screened. The percent of potential students screened at each grade level was as follows: kindergarten, 82% (n=241); grade 1, 82% (n=215); grade 2, 89% (n=251); grade 3, 73% (n=240). Time factors restricted rescheduling of screenings for the 7% of students (n=76) who were absent.

Classroom noise measurements

Another audiologist, the fourth author, measured the noise levels in 26 unoccupied classrooms in two participating schools in one school district. The classrooms in one of these schools (School X) were amplified and the classrooms in the other school (School Y) were unamplified. The average ambient noise level was measured with an A-weighted scale using the ANSI S12.60 standard of 35 dB with a 2 dB tolerance (Acoustical Society of America, 2002). The A-weighted scale is the measurement standard that most closely approximates the human ear.

Noise level measures were recorded at the key location in each room as per the ANSI guidelines. A Quest 2900 Integrating Average/ Data Logging sound level meter (SLM) was mounted on a tripod set at .8 meters, consistent with a typical seated position of a child. The SLM was held while walking around the classroom seating and standing area. Real time measurements were taken to find the area with greatest noise level. This was considered to be the key location. The SLM was placed on the tripod at the key location. Five 1-minute measurements were taken at the key location in each room. The five readings were averaged to determine the overall background noise level. The lowest reading at the key location was subtracted from the highest reading to find out if the background noise level was within the ANSI conformance tolerance. A difference of 2 dB or less was consistent with steady background noise levels. Unsteady background noise levels were suggested when the difference was greater than 2 dB. However, unsteady noise was not verified since a more comprehensive assessment over a longer period of time would have been necessary to confirm this suggestion.

Classroom observations

Four research assistants (RAs) were trained by the first three authors in the use of Massie's (2000) observation protocol, *Revised Environmental Communication Profile* (RECP). This structured coding system measures the dynamics of classroom communication. The data that was collected pertained to communication made by teachers and students during the normal course of events in Language Arts classes. All of the sixty classes were observed by the RAs. Each RA observed the same classes pretest and posttest (after sound field systems had been in use for 10-14 weeks). Inter-rater reliability checks were conducted both pretest and posttest with each RA by the first two authors. Inter-rater reliability results ranged from 80% to 95%.

A time sampling procedure, in which each child was observed for 30 seconds followed by a 10-second recording period, occurred four times in each class. There was a potential data set of 4032 pretest and 4032 posttest observations. Due to student absenteeism, the number of actual observations was 3543 pretest and 3519 posttest. Neither teachers nor students were aware of who was being observed.

The use of the RECP facilitated quantification of the child's verbal and nonverbal communicative interactions and the direction of communication. As shown in Appendix A, the coding scheme included two types of verbal and four types of nonverbal ways students could communicate. These communicative interactions could occur in four possible directions. If a student communicated while being observed, the environmental event was recorded which could include either a teacher's or a peer's communication.

The sources of the stimuli to the child were also recorded. It was thought that students who could hear the teacher better (when amplification was used) would respond more often to the teacher when they were addressed directly as compared to those in the non-amplified group. This would be seen on the RECP as more items recorded in the section of Child's Communicative Interactions, and the Direction of Communication would be towards the teacher. An increase in response rate from the pretest to the posttest would show that students were engaging in more communicative interactions after sound field systems were in place. Such an increase would be considered a positive result when the teacher was addressing the class. Conversely, it was thought that when an amplified teacher was addressing either the whole class or a peer, the observed student would engage in fewer communicative interactions than students in the non-amplified group. It was thought that this would occur because the student was focusing more on the teacher rather than engaging in other communications which could be off-task. In this case, a decrease in the number of communicative interactions would be a positive result.

One or more communicative interactions could occur within each observation depending on what was happening in the classroom. Since this resulted in the amplified group and the unamplified group having different numbers of communicative interactions, the data were expressed as proportions of student responses out of the total number of cues given by the teacher for each of the three types of communication. The data were then tested for significance of the difference between two independent proportions. The z-ratio and associated one-tail and two-tail probabilities for the difference between two independent proportions were calculated. Pretest and posttest results were compared within both the amplified and unamplified groups.

Participant interviews

At the posttest stage of the study, the third author conducted 62 semistructured interviews in each of the 31 amplified classes. Interviews were conducted individually with the 31 teachers using the following open-ended questions: What has having this system in your classroom meant for you? What differences has the system made for you and your teaching? What have you noticed about the children's responses when you used the system? Elaborating probes were used to elicit further information (Creswell, 2005).

The students in each of the 31 classes were interviewed as groups using general questions pertaining to what they liked or disliked about the sound field systems in their classrooms and whether they noticed any differences when the systems were used. Probes were used in these discussions to help the students elaborate their responses more fully. The student data was analyzed by interview, rather than by participant, since the interviews were conducted in groups.

Teachers' and students' perceptions about their experiences using the sound field amplification systems were digitally recorded and transcribed verbatim. The transcripts were read repeatedly to become familiar with the content and to listen for emerging themes. Using a word processing program, blocks of data were marked with the same colour when they pertained to a particular category. These categories were sorted and reduced into descriptive themes by combining overlapping concepts. An experienced educator, independent of the research, then reviewed the data and the proposed themes to determine their compatibility from an educational perspective (Sandelowski, 1986).

RESULTS

Hearing screenings

Figure 1 shows the results of the hearing screenings for kindergarten, grade 1, grade 2, and grade 3.

Out of the total 201 students who did not meet this study's criteria for adequate hearing, there were at least six possible audiology clinics in the region that may have provided follow-up. Results were provided by only one of these clinics where fourteen of the students were seen. Eight of these students had normal hearing and were discharged. Five students who had conductive hearing loss were referred for medical treatment. One student was diagnosed with permanent bilateral sensorineural hearing loss and was fitted with hearing aids.

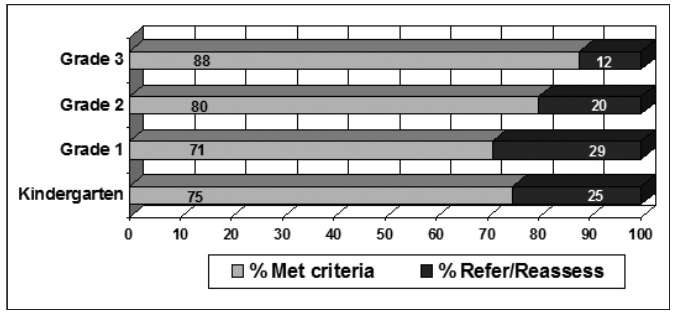

Figure 1.
Percentage of students by grade level who met the criteria for adequate hearing, and those who needed to be referred or reassessed.

Classroom noise measurements

The acoustic measures taken in the two schools referred to as School X and School Y are shown in Tables 2 and 3.

The mean ambient background noise level of the classrooms ranged from 33.6 dBA to 52.3 dBA. All 14 classrooms in School X failed to meet the ANSI standard for adequate listening conditions (Acoustical Society of America, 2002). The noise state was either steady according to ANSI standards or unverified. All but four classrooms in School X had steady noise. In those classrooms where the noise state was unverified, a

Table 2
A-Weighted Sound Level Readings in the Key Location, Mean Ambient Noise Level, and Noise State for Classrooms Tested in School X

Room	Key Location Measurements in dBA (1 min average)					Mean Ambient Noise Level	Noise State
X1	45.4	44.8	45.5	46.2	45.8	45.5	Steady
X2	53.0	53.1	52.8	48.2	42.6	49.9	Unverified
X3	49.9	49.0	48.9	48.9	48.9	49.1	Steady
X4	46.6	46.6	46.6	46.7	46.8	46.7	Steady
X5	45.3	45.2	44.8	45.1	45.4	45.2	Steady
X6	52.3	51.5	49.6	49.7	49.8	50.6	Steady
X7	40.8	41.7	41.4	41.2	41.1	41.2	Steady
X8	51.0	47.1	46.6	46.7	43.8	47.0	Unverified
X9	46.8	47.1	50.9	46.9	45.9	47.5	Unverified
X10	47.9	48.0	48.3	48.0	48.2	48.1	Steady
X11	55.5	51.6	51.6	51.3	51.3	52.3	Unverified
X12	50.7	49.2	49.1	49.0	49.0	49.4	Steady
X13	47.4	47.3	47.4	47.5	47.5	47.4	Steady
X14	43.5	43.4	44.2	43.1	43.4	43.5	Steady

Note: A level of 37 dB was accepted as the standard for the noise level of the classrooms in this study using the guidelines of the Acoustical Society of America (2002).

Table 3

A-weighted Sound Level Readings in the Key Location, Mean Ambient Noise Level, and Noise State for Classrooms Tested in School Y

Room	Key Location Measurements in dBA (1 min average)					Mean Ambient Noise Level	Noise State
Y1	34.7	34.0	34.3	33.9	34.2	34.2	Steady
Y2	36.0	36.3	35.1	35.5	35.6	35.7	Steady
Y3	36.6	35.4	35.1	35.0	35.0	35.4	Steady
Y4	39.2	37.1	38.3	36.8	36.7	37.6	Steady
Y5	38.5	38.7	38.7	38.5	38.9	38.7	Steady
Y6	36.4	36.5	36.6	36.2	36.7	36.5	Steady
Y7	38.8	39.2	39.2	38.7	39.2	39.0	Steady
Y8	36.4	35.8	35.4	35.2	35.4	35.6	Steady
Y9	34.8	33.2	33.7	33.0	33.3	33.6	Steady
Y10	38.7	36.4	37.4	37.0	36.3	37.0	Steady
Y11	41.3	44.3	45.3	46.1	46.1	44.6	Unverified
Y12	36.7	36.7	37.0	36.8	36.8	36.8	Steady

Note: A level of 37 dB was accepted as the standard for the noise level of the classrooms in this study using the guidelines of the Acoustical Society of America (2002).

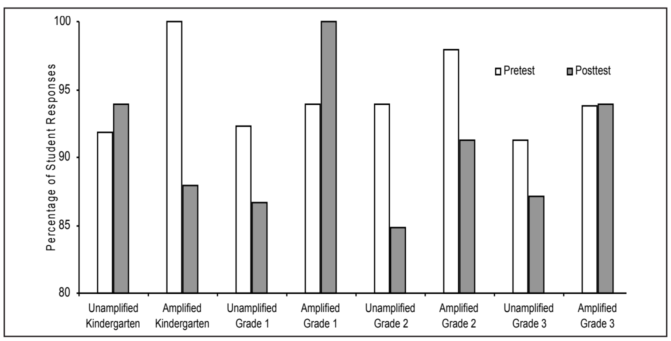

Figure 2.
Percentage of student responses to statements made by the teacher directly to the child in unamplified and amplified classes by grade level.

one-hour average background noise measure would be required to verify if the background noise was steady or unsteady. The HVAC system was a major contributor to the noise levels. Following the HVAC system noise reduction after regular school hours, two classrooms were retested and showed a significant background noise reduction of 12.5 and 14.2 dBA. In School Y, all but one of the 12 classrooms had steady noise. Four classrooms in School Y failed to meet the ANSI standard for noise level.

Classroom observations

The data gathered from the RECP included the individual student's verbal and nonverbal communicative interactions, the teachers' and peers' communicative interactions, and the source of the stimulus. Communications that the student initiated towards him- or herself were not included in the analysis. For this study, teachers' nonverbal communications and peers' communications were excluded since the focus was on voice amplification of the teacher. Regarding the sources of stimuli, cues between peers and environmental noise were excluded along with cues to the child or the class from the peer.

The following sections discuss the results of the classroom observations when the three sources of stimuli occurred: (a) cues to child from teacher (n=742); (b) cues to class from teacher (n=5042); and (c) cues to peer from teacher (n=920).

Cues to the child from the teacher. Figure 2 shows the response rate from students was high (over 85%) in all groups. It was hypothesized that students would respond more to amplified teachers when addressed directly. This pattern was shown in grades 1 and 3. In kindergarten, student responses decreased when amplification was used. In grade 2, they decreased but not as much as in unamplified classes. Significance levels in the individual grades could not be calculated due to small sample sizes.

As shown in Figure 3, when the data from grades 1 to 3 were combined, the decrease in responses in the unamplified condition was significant (z=1.684, p<.05).

No significant change in the amplified condition was seen. In kindergarten, the reverse response pattern was noted.

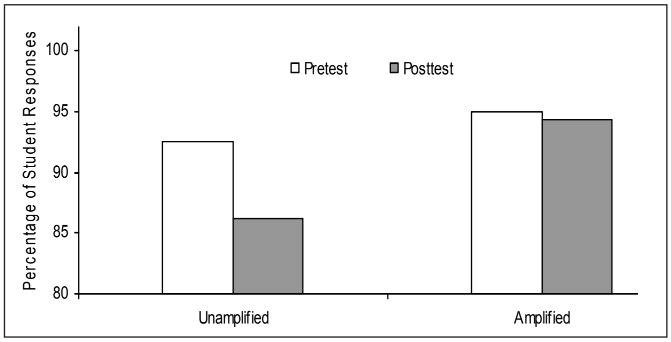

Figure 3.
Percentage of student responses to statements made by the teacher directly to the child in unamplified and amplified conditions in grades 1 to 3 combined.

Cues to the class from the teacher. Figure 4 shows decreases in the number of communicative interactions over time when the teacher addressed the class. In the unamplified classes, in kindergarten and grades 1 and 2, the decrease was not significant. There was a significant decrease in the unamplified grade 3 classes (z=1.963, p<.05). In the amplified groups, the decrease was significant in grade 1 (z=2.298, p<.05), grade 2 (z=1.709, p<.05) and grade 3 (z=2.375, p<.01). The decrease in kindergarten was greater in the amplified group, but was not significant.

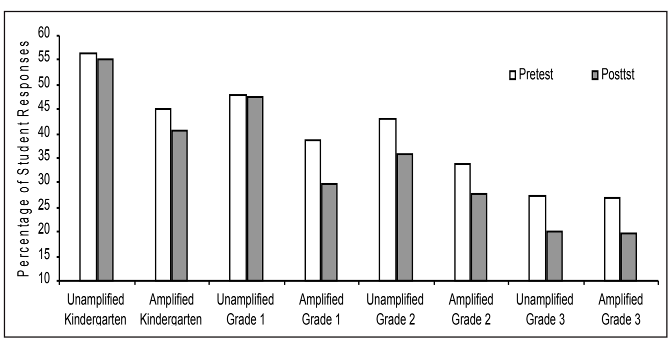

Figure 4.
Percentage of student responses to statements made by the teacher to the class in unamplified and amplified classes by grade level.

As shown in Figure 5, when the data from grades 1 to 3 were combined, the decrease in student response rate was significant in both groups, but not as strong in the unamplified condition (z=2.101, p<.05) as in the amplified condition (z=3.55, p<.01).

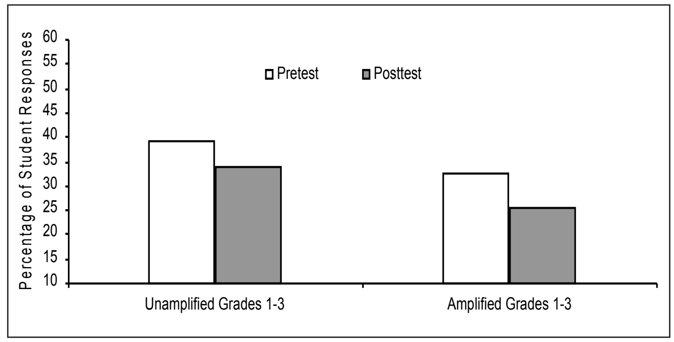

Figure 5.
Percentage of student responses to statements made by the teacher to the class in unamplified and amplified classes in grades 1 to 3 combined.

Cues to a peer from the teacher. Figure 6 shows the percentage of student responses when the teacher addressed a peer of the student being observed. In the unamplified classes, there was a significant decrease in student response in kindergarten (z=1.84, p<.05), no significant differences in grades 1 or 2, and a significant decrease in grade 3 (z=3.143, p<.01). In the amplified kindergarten classes, students did not respond during pretest observations. Posttest response rates were similar to those in the unamplified kindergarten classes. The sample size was too small to calculate significance levels in the amplified kindergarten group. Significant decreases in response rate were found in the grade 1 (z=3.452, p<.01) and grade 2 (z=3.191, p<.01) amplified classes. In grade 3, the student responses did not change significantly in the amplified classes.

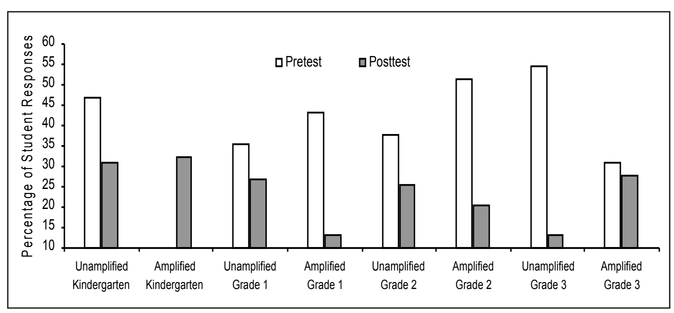

Figure 6.
Percentage of student responses to statements made by the teacher to a peer in unamplified and amplified classes by grade level.

When the data for grades 1 to 3 were combined (Figure 7), the percentage of student communicative interactions decreased significantly in both the unamplified (z=2.792, p<01) and the amplified classes (z=3.697, p<.01).

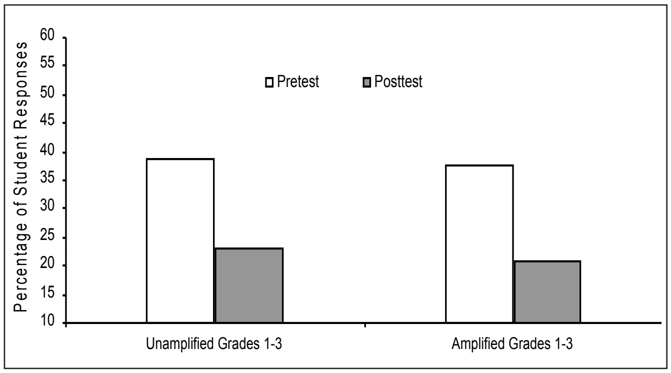

Figure 7.
Percentage of student responses to statements made by the teacher to a peer in unamplified and amplified classes in grades 1 to 3 combined.

Participant interviews

In the interviews, 11 broad coding categories were uncovered. The frequency differed for teachers and students as shown in Table 4. Through the qualitative analysis of the teacher interview data, six themes were generated. These themes occurred in the interviews with frequencies of 74% to 87%. The themes were: the need for increased education about the technology; calm, relaxed learning environment; increased student attentiveness; efficient use of class time; increased participation of all students; and improved teacher health. Each of these themes is discussed below and representative examples of teachers' comments are given to further illustrate each theme.

There was a need for more than the initial education on the use of the sound field systems. A majority of the teachers (27 out of 31, 87%) reported that they had to resolve some issues regarding operation and care of the systems, such as recharging the batteries, avoiding feedback, ensuring that the microphone was clear of objects like clothing and jewelry and avoiding amplification of vocal sounds such as coughing. A grade 1 teacher noted, "If you have a piece of paper in front of [the microphone] and it squeals it startles [the students]." Also, a grade 3 teacher stated, "I've structured my classroom so we're not getting [feedback] any more."

Some teachers (24 out of 31, 77%) described the classroom environment as being more relaxed when the students could hear the teacher clearly. They stated that other classroom noises seemed less prevalent and students could hear them wherever they were in the room. "The noise level in the class really goes down when I use [the sound system]" stated a grade 1 teacher. A grade 2 teacher said, "The kids do comment that they're hearing me in every corner of the room." A grade 3 teacher stated, "Now I'm just able to be on an even keel for the whole day. I find they're all a little more relaxed."

Many teachers (24 out of 31, 77%) found that students were more attentive when the sound field system was used. A kindergarten teacher remarked, "It's just so much clearer, even if their eyes aren't on me, they can tell me what I said. My voice doesn't blend in anymore." A grade

Table 4
Percentage of Occurrence of Coding Categories

Coding Category	Teachers	Students
Acceptance/positive attitude toward sound field systems	87	0
Improved student attending and learning	77	61
Voices heard over the background noise	74	100
Teachers' voices more rested/teachers less tired	74	23
Teachers develop strategies for using sound field systems	74	23
Basic understanding of the operation of the system	74	32
Feedback noted as a problem	48	65
Students with soft voices and shy students more willing to speak	42	20
Inclusion of students with special needs	39	0
Microphone needs to be clear of objects and non-speech sounds	39	32
Volume set too high	16	52

1 teacher stated, “Children are more attentive whenever I turn the system on. They tend to look at me more”.

When using the amplification system, teachers (24 out of 31, 77%) stated that they were able to use class time more efficiently and could focus on presenting new information. They found that they could move around the room and be heard clearly by all students. A grade 1 teacher said, “I don’t have to repeat as much,” while a grade 3 teacher noted that prior to using the system, “sometimes I would have to take time to come way over to get to [the students], touch them because they wouldn’t hear me. But at least with this system I can get their attention from where I am. It’s quicker, it’s faster, it’s easier that way.”

In Canada today, with the philosophy of inclusion, there is a greater variety of learning needs in every classroom. The teachers in this study (23 out of 31 teachers, 74%) felt they were creating more inclusive classrooms due to increased participation of students when sound field amplification was in use. A grade 1 teacher described using the pass-around handheld microphone by saying, “There are [quiet] children that would take part, but we would never hear what they have to say. I would always have to repeat for the other children to be able to hear. Now, they can actually say what they need to say and everyone else hears them saying it.” A grade 2 teacher said “[the handheld microphone] seems to give kids a sense of empowerment.” Inclusion of children with a variety of learning needs was also highlighted by about half of these 23 teachers. They noticed that students with special needs were able to attend for longer periods and take part more in classroom activities. One of the grade 1 teachers expressed this idea by saying, “…the one we thought might have a central auditory processing disorder…he’s really started to speak and participate.”

Many teachers (23 out of 31, 74%) commented that they had had vocal health issues, such as sore throats, vocal strain, and laryngitis from projecting their voices. They stated that the amplification system improved these problems and also helped them feel less tired. The teachers found that they could communicate at a comfortable volume without additional effort to make themselves heard. One kindergarten teacher noted, “I don’t have to strain. I end up with a lot of sore throats. I haven’t had a sore throat since [using amplification].” A grade 3 teacher remarked, “I wasn’t straining [or] having to talk loud anymore. My throat finally got better and I’m not as tired at the end of the day.”

Discussions were held with the students in each of the amplified classes. The number of students in each class who chose to respond to the researcher varied. Further, older students were generally more articulate than younger students. Often, the younger ones strayed from the topic and needed to be redirected with more questions. Analysis of the data revealed that the student focus was predominantly on categories related to what they could hear and how they connected that with their learning. The students’ data is presented using the coding categories (Table 4) rather than the educational themes since the students concentrated mainly on sounds and not on teaching practices. The students’ six highest categories are described below and representative examples of their statements are given.

In all of the classes, students mentioned that the sound systems helped them hear well because voices were louder. A grade 1 student said, “When we didn’t have the [sound system and the handheld] microphone … we couldn’t hear anybody so since we have it, we can hear them perfectly.” In a kindergarten class, one young student noted, “We can hear our teacher much gooder.” In 61% of the classes, students mentioned that the sound field system helped their learning. “I’m glad we got that [sound field system] because now it’s a lot easier to learn and understand what our teacher is saying” was a statement made by a grade 3 student, while in a grade 2 class, a student acknowledged that “Now, when I hear, I know what to do.” Also in grade 3, students remarked, “I listen better when she has the speaking thing on. I like it because it helps my learning … so I can hear better and get my work done” and “Now that we have the microphone we’re learning a lot more and we’re actually listening and not fooling around.”

In some of the classes, the students spoke about problems they noticed in the use of the sound system, including occasional feedback (65%), volume set too high (52%), and interference from objects touching the microphone or vocal sounds, like coughing (32%). Also, in 32% of the classes, students mentioned that sometimes teachers forgot to charge the batteries or turn the microphone off when they left the room or turn it on when they were teaching the class. A grade 2 student noted the problem of feedback by saying, “the speakers squeak when our teacher gets too close to them” while a grade 1 student pointed out the problem of setting the volume too high by saying “When it’s turned up too loud, I don’t like it.” A grade 2 student mentioned that “When [the teacher] blows her nose, it’s really loud.” A grade 3 student stated, “When the teacher … forgets to turn it on we can tell a big difference and we have to remind her to turn it on.”

DISCUSSION

This study illustrates some of the elements involved in creating optimal classroom listening environments in the early school years. The practical implications which emerged were related to students' hearing status, classroom acoustics, and the use of sound field amplification.

Hearing screenings

The results of the hearing screenings revealed that only 71 to 88 percent of the students tested met the criteria established in this study for adequate hearing levels. While the screening methods and criteria used by researchers vary, the findings and those of the present study highlight the need for hearing screening programs in the early school years (Niskar et al., 1998; Serpanos & Jarmel, 2007; Yockel, 2002). Identification of students with hearing problems could lead to earlier medical and educational interventions, which may reduce the impact of hearing loss. Niskar et al. (1998) point out that screenings should include testing high and low frequency ranges. In addition, there needs to be a plan for students who do not pass the initial screening, such as including an assessment of middle ear status to ascertain the nature of the hearing problem (Yockel, 2002). While the present study focused only on the early school years, Serpanos and Jarmel (2007) note that hearing screenings are also needed throughout childhood to help identify late onset or acquired hearing loss.

Classroom noise measurements

The results of this study were consistent with previous research, which revealed high levels of background noise in many classrooms (for a review see Picard & Bradley, 2001). Suggestions for improvement of the listening conditions in classrooms with poor acoustics have been well documented in the literature (Berg, Blair, & Benson, 1996; Choi & McPherson, 2005; DiSarno et al., 2002; Edwards, 2005; Siebein, 2004; Siebein et al., 2000). While this study did not evaluate the need for physical modifications to the classrooms, it has been noted in the literature that structural modifications should be considered before implementing sound field technology (Nelson & Soli, 2000). Also, as Palmer (1998) noted, the distance between the teacher and students may contribute to unfavourable listening conditions as teachers move around the room. Thus, structural modifications may still not provide a uniform S/N for all students in the room.

It was noted in the present study that the HVAC system in two classrooms created unfavourable listening conditions. When the systems were turned off, there was a reduction in noise level, but the systems could not be turned off during school hours due to the design of the building. There are currently no Canadian building code standards for classroom acoustics. Implementation of recognized standards would increase the likelihood of new or renovated school construction incorporating acoustical features that result in favourable listening conditions for students. Experts such as audiologists or sound engineers familiar with standards for room acoustics can have a distinct role in the planning stages for new school facilities as well as evaluating and addressing problems with existing classrooms (Seep et al., 2000; Siebein, 2004; Smaldino, Doggett & Thunder, 2004).

Classroom observations and participant interviews

Classes were observed in their naturalistic context with no attempt made to alter the teaching methods or content. The only constant was that observations occurred during Language Arts classes. Variation in teaching approaches may have contributed to the differences in student response rates that were found among the classes at pretest. While the classes were different at pretest, the classes in each condition were compared to themselves posttest and not to each other. A number of factors may have contributed to changes such as how teachers used the sound systems and which teaching approaches were used during the study. Other factors may also have had unknown effects on the results which could account for why there were changes in the unamplified classes. In addition, the changes in the amplified classes were not always in the expected direction and were not always significant. However, we would argue that, in general, some of the trends in the amplified classes were in the expected direction and showed that amplification had a positive effect. The interviews clarified the participants' perceptions of what occurred while the amplification systems were being used. The interviews helped to interpret the observational data. Some of the data gathered in the classroom observations showed that students in amplified classrooms responded more to the teacher when they were being directly addressed. Similar to other research findings, the teachers in this study found that students paid better attention and understood verbal instructions more efficiently when sound field amplification was used (Cornwell & Evans, 2001; DiSarno et al, 2002; Eriks-Brophy & Ayukawa, 2000). The interview data supported the idea that students' higher rates of response in amplified classes may have been due to improved attention. Conversely, the observational data showed students' decreased communication when the teacher was addressing the whole class or a peer. This was also supported by teachers' comments regarding students' increased focus on the learning tasks.

The findings from the participant interviews were consistent with DiSarno et al. (2002) and Flexer (2005). They showed that teachers, when amplified, felt they could move freely around the classroom without the concern of how well students heard their messages, allowing for more efficient use of class time. Students sitting in all parts of the room continued to hear the teacher's voice at a constant volume even though the distance between the teacher and students changed. Similar to Eriks-Brophy & Ayukawa's (2000) findings, teachers in this study felt that when they used amplification, their classroom became a more inclusive environment. They noted greater involvement in class activities and that students with exceptionalities could more easily focus, take risks, be drawn into the learning environment, and engage with others.

The pass-around handheld microphones were also noted as beneficial to the learning environment. Flexer (2005) explained that pass-around microphones improve students' ability to hear each other, thus enabling them to capitalize on incidental learning opportunities and engage in auditory self-monitoring. In the participant interviews, teachers noted that the voices of quiet students could be heard and there was less need to ask them to speak up. In addition, shy students were more likely to participate when they could use a handheld microphone.

The teachers experienced improvements in their health with the use of amplification. As was found with teachers interviewed by Palmer (1998) and Eriks-Brophy & Ayukawa (2000), teachers in this study felt more relaxed, less stressed and less fatigued. Consistent with other findings in the literature, there was a reported reduction in sore throats and laryngitis and loss of work time associated with these conditions (Jónsdottir et al., 2003; Picard & Bradley, 2001; Sapienza et al., 1999). When teachers maintain voice health, fewer substitute teachers are needed which helps the continuity in students' education.

The interview data suggested that teachers needed more education on the sound field systems. Flexer (2005) recommended that individuals knowledgeable in classroom acoustics should provide information on the setup, operation, and rationale for the equipment and create opportunities to practice with it. In addition to initial education, follow-up sessions would help to ensure continued effective use of the technology. The preparation of a training package for substitute teachers would also be beneficial.

LIMITATIONS AND FURTHER RESEARCH

Hearing screenings

A number of factors may have affected the sample of students who were screened. It was not known how many parents of students with hearing problems withheld consent for screening if an audiologist was already following their children. Testing was spread across winter and spring months due to the limited availability of qualified hearing screeners. It is unknown whether this extension across seasons may have affected the sample due to the potential influence of seasonal health problems (Flexer et al., 1994). Another factor that may have affected the results was the ambient noise level in the rooms used for screenings. Although the rooms used were subjectively assessed, sound level measures were not taken.

Time limits did not allow follow-up school visits to screen students who were absent or rescreen those who did not pass the initial testing. While follow-up by an audiologist for fourteen students was reported to the authors, it is unknown how many other students who did not meet the criteria of the screening were assessed by other audiologists. Future research should allow time for repeat visits and for follow-up of all identified students to better understand the nature of their hearing problems. Such research would provide a more complete profile of the hearing status of the target population and could potentially lead to better educational outcomes for those students who have hearing loss.

Classroom noise measurements

The noise levels in only two of the schools were measured. One limitation was that the noise level in School X was higher than in School Y. It is unknown whether these schools are representative of the variability of the schools in this study. More schools could not be tested since time was not available to cover the geographic distance among all of the schools. Further research could be done with a larger sample of buildings that represent the variability in school designs.

Time and equipment restrictions limited the number of acoustic measures that were taken at the two selected schools. Other measures, such as reverberation, distance, and the influence of teachers and students on background noise could also be included to provide a more thorough evaluation of the classroom acoustics. As well, the present study used only an A-weighted scale to measure the classroom noise. Further research using a C-weighted scale would provide additional acoustic measures (Crandell et al., 2004).

Classroom observations

Four research assistants were needed in order to collect data within the same pretest and posttest periods since observations were made only within Language Arts subject area classes. For the same reasons, two researchers were needed to conduct reliability checks concurrently. Since the RECP was a complex data collection instrument, inconsistency among observers and researchers was a possible limitation.

Sample size in each classroom was too small to allow for exclusion of students who were not present in both the pretest and posttest observation periods. Follow-up for students who were absent was not part of the procedure because classroom environments, types of lessons, student groupings, or teaching styles could change from day to day.

The content and purpose of students' responses was not recorded, nor were teachers' methods for delivering instruction. Since this information was not included in the classroom observations, the relationship between instructional method and classroom observations could not be analyzed. Future research could include more descriptive measures of the teaching-learning environment. Another study might involve observing students only during times of pre-selected instructional methods. Additionally, in the present study, English and French Immersion class data was not separated in the analyses. A further investigation could focus on French Immersion classes where teaching methodology incorporates both second language and content learning.

The results from the observations in kindergarten classrooms often differed from those of the other grades. It is not known if the communicative interactions and pedagogical methods associated with verbal instruction used in kindergarten may vary from those used in other grades. Further study at the kindergarten level could be designed to consider these variables.

The use of the RECP as a recording protocol was limited in terms of the type and amount of observational data that could be recorded. The time sampling procedure allowed for only brief observations. Since the content of the communicative interactions were not videotaped, the context was not known and could not be part of the analyses. Only the frequency of responses by students could be analyzed. Further study of classroom interactions might include data on the content of the teachers' and students' communication and the context.

Participant interviews

Time factors limited the ability to probe more deeply into participants' comments during the interviews. Additional time would have allowed for follow-up visits to verify the themes and elaborate on what was said. Three areas for future research emerged from the interviews.

First, the benefits of sound field amplification on teachers' vocal health could be measured by investigating absenteeism related to vocal hygiene problems. Such a study could also measure the cost of replacing teachers with substitutes including the potential impact on students of reduced continuity in teaching.

Second, some teachers commented that they had questions regarding the use of the technology. The schools had variations in the length of time sound field systems were used, how they were installed, and the technical support provided. Future research could ensure that all teachers receive the same instruction, including information on the setup, operation, and rationale for the use of the equipment as well as periodic follow-up sessions by individuals knowledgeable in acoustics and the use of sound field technology.

Third, the use of handheld microphones in the classroom is another area for further research. While this study focused mainly on the amplification of the teachers' voices, increasing the volume of students' voices may have additional benefits on student engagement in the learning process.

CONCLUSION

This research contributes to the understanding of the classroom listening environment in a Canadian context. The data in this study, along with current literature, suggests that rooms with poor acoustics require students to use more effort to attend and concentrate. This study also highlights the importance of addressing hearing problems among students in the early grades. School personnel need to be aware of the many components involved in creating optimal classroom listening environments including characteristics of the students, room acoustics, and benefits of using sound field amplification. Enhancing the listening environment and enabling students to hear in the classroom is critical because so much learning is based on accurately perceiving the message.

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APPENDIX A

Revised Environmental Communication Profile*

(Massie, Theodoros, Byrne, McPherson, & Smaldino, 1999)

Class: ____________ School: ____________ Date: __________ Start: _______ Finish: ______ Page ____ of ____

CHILD'S COMMUNICATIVE INTERACTIONS										ENVIRONMENTAL EVENTS																
Verbal		Nonverbal				Direction of Communication				Verbal		Nonverbal				Verbal		Nonverbal				SOURCE OF STIMULI TO CHILD				
										TEACHER						PEER										
Statements	Other Vocal Behavior	Eye Contact	Tactile	Gesture	No Response	Initiations to Teacher	Initiations to Peer	Initiations to Class	Initiations to Self	Statement	Other Vocal Behavior	Eye Contact	Tactile	Gesture	No Response	Statement	Other Vocal Behavior	Eye Contact	Tactile	Gesture	No Response	Cues to child from teacher or peer	Cues to class from teacher or peer	Cues to peer from teacher	Cues Between Peers	Noise/Environment

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