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CLASSROOM AMPLIFICATION BENEFITS FOR
ACADEMIC SKILLS AND SPEECH RECOGNITION

JEFFERY B. LARSEN
AND
CHAD NYE

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Classroom Amplification Benefits for Academic Skills and Speech Recognition

Jeffery B. Larsen
Utah State University

Chad Nye
University of Central Florida

Scenario

Paula is the principal of an elementary school in a small town in the Pacific Northwest. She recently attended an education conference and met the vendor of a classroom amplification system. This vendor was very persuasive and presented some intriguing information about the benefits that classroom amplification could offer children. Paula is aware that her school was built 30 years ago and that the noise levels and the “echo” in some classrooms make it tough for some kids to understand what the teacher is saying. With pressure from the No Child Left Behind (NCLB) standards, Paula is always looking for ways to support teachers and their school meet the criteria set out by NCLB.

When Paula returned from the conference, she began investigating classroom amplification on the internet. She found several interesting articles that were very positive toward classroom amplification. She also found a position statement from the Acoustical Society of America (American Institute of Physics, 2006) that discouraged the use of classroom amplification as a routine solution for poor classroom acoustics. Most of the sites Paula visited reported opinion pieces or sales materials, not studies. Paula was determined to find studies that helped demonstrate whether classroom amplification was beneficial.

Background

Despite the evidence that poor acoustic conditions are detrimental to learning, there appears to be a continuing interest in the use of classroom amplification as a potential solution for poor acoustics in school classrooms. Proponents of classroom amplification systems essentially claim four benefits: (1) improved SNR, (2) improved speech recognition, (3) reduced vocal abuse on the part of teachers, and (4) improved academic achievement. Classroom amplification is not without detractors (American Institute of Physics, 2006; Lubman,

2005) who maintain that classroom amplification is ineffective or less effective in rooms where the reverberation time (RT) is high (higher than 0.6 seconds, as recommended by the ANSI 12.60 standard) and that classroom amplification systems add more noise to already noisy rooms.

Studies show that many (if not most) classrooms in North American schools have suboptimal acoustical conditions for speech communication (Blair, 1977; Crandell & Smaldino, 1995; Finitzo-Hieber, 1988; Picard & Bradley, 2001). Studies show that acoustic properties of classrooms, including noise, reverberation, and distance, significantly affect the speech recognition performance of listeners. Noise is defined here as any undesired sound. It has the most significant influence on a word recognition score in a classroom (Bradley, 1986; Houtgast & Steeneken, 1973; Knudsen, 1929). The difference between the intensity of the signal you want to hear and competing noise is commonly referred to as the *signal-to-noise ratio* (SNR, French & Steinberg, 1947). The average SNRs measured in classrooms range from -7 dB (Blair, 1977) to $+9.5$ dB (Houtgast, 1981). Blair (1996) reported optimal SNR values as $+15$ dB for listeners with normal hearing and $+30$ dB SNR for listeners with hearing loss.

Reverberation, the reflected sound in a room, is measured by the time in seconds it takes for a sound to decrease in intensity by 60 dB in the room. This measure is called reverberation time (RT). High levels of reverberation are detrimental to word recognition in classrooms (Finitzo-Heiber & Tillman, 1978; Houtgast & Steeneken, 1973; Nabelek & Robinette, 1978). The distance between the student and the teacher also causes the power or energy of the speech signal to decrease rapidly (Beranek, 1986), affecting speech recognition.

The established relationship between poor acoustics and poor speech recognition in classrooms provides at least an intuitive argument that improving the acoustic environment of a classroom results in benefits for the academic performance of listeners. Due to the complex nature of speech perception (Juszyk & Luce, 2002) and

the myriad of variables that influence academic performance, designing well-controlled studies that establish a causal relationship between poor classroom acoustics and poor academic performance is problematic. Nevertheless, correlations between poor acoustic conditions and reduced classroom performance have been described for cognitive tasks (Cohen, Evans, Krantz, Sokols, & Kelly, 1981), performance on a general reading skill assessment instrument (Bronzaft & McCarthy, 1975), performance on math skills (Zentall & Shaw, 1980), and for age-level reading performance (Blair, 2005; Gertel, McCarty, & Schoff, 2004; Green, Pasternack, & Shore, 1982). The evidence of poor acoustic conditions existing in current classrooms in the United States has led to calls for rooms used for speech communication to have low values of both noise and RT (ANSI, 2002; ASHA, 1995; Bess, 2001; Crandell & Bess, 1986; Crandell & Smaldino, 2000; Siebein, Gold, Siebein, & Ermann, 2000).

For all these reasons, the advantages of adoption of sound field amplification in the classroom are open to question as an intervention that will improve student performance in the classroom. Thus, the purpose of this Brief is to assess the impact of classroom amplification on academic performance and speech recognition for elementary school age children.

Method

Paula chose to continue her search for studies using the Quick Response Review (QRR). The QRR is a process of information retrieval, data extraction, and analysis that provides preliminary answers to questions, using the methods of a full systematic review. The advantages to the QRR are that (1) it's useful when resources are limited and (2) the interest is in providing a more general understanding of the intervention. The primary disadvantages of the QRR are that (1) the sources of information retrieval are restricted to those that are relatively easily accessed, and (2) the data analysis only focuses on major outcomes with limited attention to moderating variables that might provide a richer understanding of the conditions under which the outcomes were assessed.

Inclusion Criteria

Paula set up the following criteria for identifying potential studies that assessed the impact of classroom

amplification:

1. Peer-reviewed journal
2. Published between 1990 and December 2009
3. Reported results of academic performance or speech recognition outcomes
4. Participants were typical children in an elementary or middle school setting

Paula recognized that these criteria meant that opinion papers, conference reports, government reports, dissertations, or book chapters would not be included. Because resources and time were limited, the QRR provided a reasonable alternative to a full-fledged, systematic review. Paula included only measures that quantitatively assessed the impact of the classroom amplification; she excluded studies that reported only affective or behavioral outcomes.

Information Retrieval & Search Strategy

One important consideration for a QRR is the universe of databases from which information will be searched. As an elementary school principal, Paula's access to a wide range of databases was limited to

- Google/Google Scholar,
- ERIC,
- PUBMED, and
- ASHA (available with the assistance of the school SLP).

Paula used the following terms and their synonyms as indexed in each database, either individually or in combination, to identify potential studies for inclusion:

- Classroom amplification
- Room acoustics
- Academic performance
- Classroom amplification and student participation

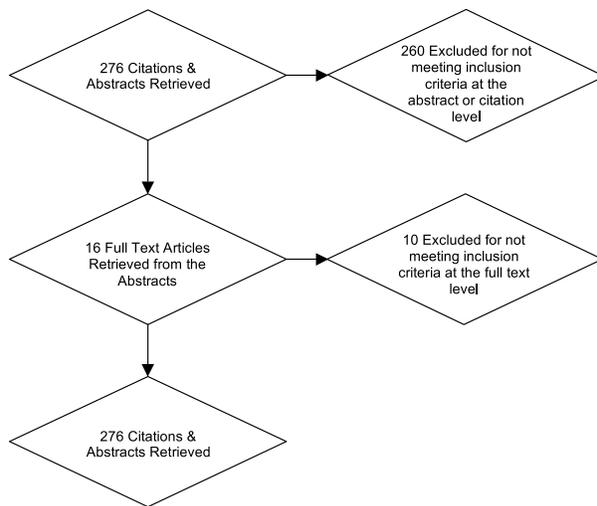
Results

Information Retrieval

Paula identified 276 potential studies with intervention and outcome measures that might help her decide about implementing a classroom amplification

program. Figure 1 provides a summary of the studies identified and included or excluded at each step of the information retrieval process.

Figure 1. Flow chart for study inclusion/exclusion decisions



A review of the six studies that met the QRR criteria showed that there was considerable variability in the acoustic conditions under which the classroom amplification systems were evaluated (see Table 1). The dependent variables and study designs also were very different from one study to the next.

The results reported were generally positive, but an analysis of the quantitative outcomes of these studies caused Paula to seriously question the evidence basis for justifying the use of classroom amplification. The performance-based outcomes of behavior and academic performance, and speech recognition performance presented in the included studies are included in the following summary of acoustic conditions.

Summary of Acoustic Conditions

For a classroom amplification system to have any effect, the system must improve children's ability to hear the teacher's voice. The key measure used to determine how well a classroom amplification system helped a child hear is the signal-to-noise ratio (SNR). The average SNR

Table 1. Acoustic impact of the classroom amplification system

Study	SNR without classroom amplification	SNR with classroom amplification	How measurement was made	Implications
Zabel (1993)	-3 to 0 dB	+10 dB	At 5 sites throughout the classroom	Measurements made across classrooms specify the effect of amplification for listeners and demonstrate if the amplification was sufficient to influence the dependent variable.
Palmer (1998)	Not reported	+6 dB to +10 dB	Measured at "all listening areas of the room (p. 822)"	Same as implications response for the Arnold & Canning (1999) study, except that no measure close to the loudspeakers was made.
Arnold (1999)	Not reported	+10 dB at 1 meter and +6.5 dB on average at 6 locations in the classroom	Sound level meter at 1 meter and at 6 locations in the classroom	The combination of the measure close to the loudspeaker and across the classroom make the method repeatable and allow for a good characterization of what the amplification system is doing for the listeners. The lack of a SNR without the amplification system does not allow for an estimate of how much SNR increase is needed to obtain the benefits observed in the study.
Rosenberg (1999)	-3.63 dB	+3.31 dB	6 inches from loudspeaker—values represent estimate of SNR at 1 meter from loudspeaker	Measuring close to the loudspeaker is a highly repeatable measurement, but the inverse square law does not apply directly to enclosed rooms due to reflections and therefore the influence of the classroom amplification system on the SNR at the ears of the listeners is unknown.
Mendel (2003)	+ 6 dB to +10 dB	+ 6 dB	Unamplified condition—6 positions across classrooms Amplified condition—not reported	Not knowing how the SNR was measured with the amplification system and only reporting one value with no variability measures does not allow readers to know how well the amplification system is helping listeners in the room over no amplification.
Ryan (2009)	Not measured	Not measured	Not measured	Though positive effects were seen in the study, quantification of the influence of the amplification system is not possible unless the difference in the SNR at the ears of the listeners is known.

improvement of the classroom amplification systems over the condition of having no classroom amplification system was difficult to determine. Two studies reported a SNR both with and without the classroom amplification system (Rosenberg et al., 1999; Zabel & Tabor, 1993). Each study recorded the SNR at different places in the classroom.

1. Zabel & Tabor (1993) recorded the SNR at 5 locations across the classroom and reported a +13 dB increase in the SNR with the classroom amplification system.
2. Rosenberg et al. (1999) recorded the SNR at 6 inches from the loudspeakers and at 1 meter from the loudspeakers. Results showed an average increase in the SNR of the teachers' voices of 6.94 dB.

For three of the studies, location of the acoustic measurements was also an issue. Rosenberg et al. (1999) made their measures of the output of the loudspeakers at 6 inches from the loudspeaker and for both (Mendel et al., 2003; Ryan, 2009), the measurement location was unknown. It is difficult to assess the benefit of the classroom amplification system in these cases as the SNR at the ears of the listeners may have varied from positive to even negative values depending upon the distance and acoustic conditions under which the systems were employed. In those studies where the SNR at the ears of listeners was known, the link between the results of the studies and the influence of the classroom amplification systems can be viewed with some confidence. Also, Mendel et al. (2003) reported that the SNR of the unamplified condition varied between +6 and +10 dB, yet they also reported that the speech in the amplified condition was presented at a +6 dB SNR. If these reported values are correct, it is unlikely that listeners could be expected to benefit from the amplified condition because it did not offer an improvement in the SNR over the unamplified condition.

Behavioral and Academic Results

To answer her primary question of the impact of classroom amplification on academic and speech recognition outcomes, Paula analyzed two studies using Cohen's *d* for continuous outcome data and two studies using the percentage of non-overlapping data (PND) for non-continuous data. Two studies did not provide sufficient outcome data to allow for analysis.

Cohen's *d* was scaled and interpreted as equivalent to a *z*-score distribution for the studies reporting continuous

outcome data. For example, if students showed improvement from an intervention based on an achievement measure that resulted in a *d* value of .5, it could be said that an average of a half standard deviation improvement could be attributed to the intervention. Cohen's *d* is interpreted as a small (.20), medium (.50) or large (.70) effect on the outcome measured.

The PND was used for the Palmer (1998) and Ryan (2009) single-subject design studies, which reported non-continuous data. The PND provides the most usable summary statistic in which a percentage of improvement is calculated by comparing the number of treatment data points that exceed the highest baseline data point. The resulting percentage is interpreted as (a) ineffective (<50%), questionable (50%-70%), moderate (70% to 90%) and effective >90%. Palmer (1998) and Ryan (2009) followed individual participants to evaluate the influence of the classroom amplification and the PND statistical analysis of each showed strong effects for each.

Three studies reported improved behavior of students on rating scales or in terms of management time with the use of the classroom amplification system (Palmer, 1998; Rosenberg et al., 1999; Ryan, 2009). Only Palmer's study (1998) reported SNR at the ears of the listeners so that the positive behavioral benefits could be linked to a specific SNR benefit from the classroom amplification system. None of the studies were conducted with observers blinded to the treatment condition of the classroom amplification.

The only study that examined academic performance (Arnold & Canning, 1999) measured reading comprehension in two classes of 8- to 11-year-old children. The study reported the SNR at the ear level of the listeners (+6.5 dB on average), so the influence of the classroom amplification was a known variable. A within-group design and analysis of the amplification effect yielded statistically non-significant results for two of the three individual measures and on the overall performance (see Table 2).

Speech Recognition Results

Zabel and Tabor (1993) assessed spelling performance, but the study is classified under speech recognition because it was designed to see if students could spell words better when they were amplified as compared to when they were not. The study was not designed to evaluate the effect of classroom amplification on the underlying skills that lead to good spelling. The

Table 1. Descriptions and Outcomes of Research Studies

Study	Design	Sample Description	Dependent variable	Results
Zabel (1993)	Within-subject repeated measures design	two classes each of grades 3, 4, and 5	Spelling	3rd grade: $d = .709$ (95% CI = $-.292$ to 1.126)* 4th grade: $d = .664$ (95% CI = $-.273$ to 1.056)* 5th grade: $d = .726$ (95% CI = $-.300$ to 1.153)*
Palmer (1998)	ABA single-subject design was used with	Kdg = 2 1st = 2 2nd = 2	Ratings by observers on the Code for Instructional Structure and Student Academic Response (CISSAR)	Task Management= 90% Competing/Inappropriate Beh = 100%
Arnold (1999)	Counter-balanced within-subject repeated measures design	Two classes of 8 to 11 year-olds	Reading Ability	Level 1: $d = .114$ (95% CI = $-.280$ to $.512$)* Level 2: $d = .232$ (95% CI = $-.165$ to $.630$)* Level 3: $d = .047$ (95% CI = $.047$ to $.849$)* Total: $d = .265$ (95% C = $-.148$ to $.664$)*
Rosenberg, (1999)	Prospective Cohort study	431 children K–2	Ratings of students on the Listening and Learning Observation (LLO) scale.	Insufficient data to calculate effect size
Mendel (2003)	Between-subject, randomized assignment experiment	128 normal hearing children in 6 classes that were followed from kindergarten to the beginning of second grade	WIPI speech recognition test	Insufficient data to calculate effect size
Ryan (2009)	Multiple baseline design across participants	2 middle-school teachers each teaching coed 6th–8th grade physical education classes	managerial time (the time it takes to get students involved in exercise activities)	Tch 1 Tch 2 6th Grade 100% 100% 7th Grade 14% 100% 8th Grade 100% 100%

*Within group analysis does not allow for a clear causal interpretation; the effect size represents the change in performance but the precise cause of the change remains unknown

measurement of the SNR where the children were located in the classroom (+12 dB) showed that the amplification system was effective in improving the SNR. Data showed that spelling accuracy was improved with the classroom amplification more for those children farthest (greater than 10 feet) from the loudspeaker representing the teacher as compared to students within 10 feet of the loudspeaker representing the teacher's voice. The researchers reported using "independent scorers (p. 7)" which may have meant that the scoring was unbiased, but that should be made clear in future studies.

Mendel et al. (2003) assessed word recognition among listeners between randomly assigned control and

treatment classrooms. A major shortcoming of this study was that the reported +6 dB SNR did not include a description of how and where the SNR measure was obtained. The authors did not report if this measure was taken at the loudspeakers or if it simply represents an electronically determined presentation level. If no acoustic measure of the SNR was made when the speech and noise were presented from the loudspeaker, then the real SNR at the level of the listeners is unknown. Because four different classrooms were used in the study, the acoustic properties of each classroom may have resulted in significantly different SNR values at the ears of the listeners.

Conclusions

Paula observed that the results of these six peer-reviewed studies showed limited behavior, academic, and speech recognition benefits when classroom amplification is present. However, measures of the change in the SNR due to the classroom amplification system over the unamplified condition were lacking in the majority of the studies. This lack rendered the link between the amplification and the dependent variables unclear. The reporting of the measurements in some studies also was made in such a manner that the SNR at the positions of the children in the classroom was unknown. Finally, the statistical analysis of the studies reviewed in this QRR, using effect sizes and PND statistics, suggest that the evidence in support of classroom amplification is not strong enough to recommend implementation.

The most compelling results Paula found were that more and better studies are needed to make a case for installing classroom amplification that will help children academically. The lack of studies on classroom amplification and academic performance may be due, in part, to the difficulty in controlling for the myriad of factors that influence academic performance. A concern for most studies reviewed here was observer bias, where the observers in the studies were aware of both the test conditions and the objectives of the study. A second issue of concern is that some of the studies in this QRR did not control for or at least report fully their measurements of the SNR present at the ears of the listeners. This information is of paramount importance in studies of classroom amplification, because the whole goal of having a classroom amplification system is to improve the SNR for the listeners. Without studies that control for this factor and report that data clearly, any conclusions concerning the effectiveness of a classroom amplification system cannot be accurately made.

Paula finished her analysis with more questions than answers. Despite the concerns about the acoustic measurements in the studies and the fact that the evidence is not free from bias, the authors of the studies reviewed here, in the aggregate, report positive results concerning the influence of classroom amplification on the academic, behavioral, and speech recognition outcomes for students. The conclusions were based on measures of statistical significance without accounting for the magnitude of the amplification effect. The analysis suggests quite the opposite. Due to the problems of research methodology

and outcome measurements in currently available studies, Paula felt that she could not spend her school's money on broad-scale implementation of classroom amplification. However, the positive reported outcomes made Paula feel like classroom amplification has potential to help kids academically, but that more and better research was needed. Future studies will need to focus specifically on research designs that use blind observers, random assignment of participants, and include established and tested measures of academic performance, student behavior, or speech recognition. The completion of such studies will be necessary to justify the widespread use of classroom amplification and to quantify its benefits for children and teachers in classrooms.

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