# The Importance of Appropriate Adjustments to Classroom Amplification: A One School, One Classroom Case Study

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**The infrared classroom amplification systems in one elementary school building were analyzed to determine the consistency of amplification in each room. Most classroom amplification systems are installed when the building is empty and classes are not in session. These systems are also set at a level that seems appropriate to the installer. The purpose of this research was to determine what actual signal-to-noise levels are present across grades in an elementary building while classes are in session. The results revealed tremendous variability across classrooms by as much as 18 decibels with a range of +5 to +23 dB. The researchers also discovered that teachers are amenable to increasing sound levels and adjusting speakers to be more appropriate to students' needs. Recommendations are made for additional research and appropriate classroom fitting procedures.**

## Introduction

Research on the effects of noise on understanding speech in classrooms has been studied for a number of years (Berg, Blair, & Benson, 1996; Finitzo-Hieber & Tillman, 1978). These research studies ultimately led to the development of acoustic standards for unoccupied classrooms, American National Standards Institute - Standard S 12.60 (ANSI, 2002). While this was an important step forward in stipulating the acoustic characteristics of a classroom, classrooms are not unoccupied; classrooms are filled with students and teachers. Once people are added to an acoustic environment, many changes occur. The absorption properties of bodies, and the noise produced by students, alter the noise levels and reverberation within the room. In addition, the effects on classroom acoustics are variable because children are active. However, as students mature, their activity level generally lessens, and the amount of noise they generate is generally less intense. Another variable that modifies the levels of noise is the amount of control the teacher has on the students in a class.

One way to compensate for the acoustic variability present in every classroom is the addition of classroom amplification, such as infrared soundfield systems. The addition of amplification has several positive impacts on students' learning in schools. One of the greatest benefits is to increase the signal-to-noise ratio (SNR) so that all students have the opportunity to hear what the teacher is saying. Typically, infrared or frequency modulation (FM) classroom amplification systems are reported to improve the SNR by approximately 8 to 10 dB (Crandell, Smaldino, & Flexer, 1997). There are also reports that, when using amplification systems, vocal fatigue of teachers is reduced (Roy, Gray, Simon, Dove, & Corbin-Lewis, 2001; Rosenberg & Blake-Rahter, 1995), and teacher absenteeism due to voice problems is also reduced (Rosenberg & Blake-Rahter, 1995). Previous research suggests that students like the amplification because they can hear everything that is said, and they feel what they say is important when they are able to use the microphone (Rosenberg & Blake-Rahter, 1995). There is also some research that reports improved academic scores when classroom amplification systems are used compared to when they are not used (Sarff, 1981; Gertel, McCarty, & Schoff, 2004).

When infrared classroom amplification was in use and the rooms met ANSI standards (ANSI, 2002), research by Larsen and Blair (2008) measured an average SNR of +13 dB for students at various locations in these classrooms. When students were answering questions, reading, or engaged in discussions, the use of a handheld microphone by the students provided a significant improvement in their ability to be heard. While the benefits of classroom amplification are clear, there are still many unanswered questions regarding the use of these systems.

Without classroom amplification, the ability of a child to hear depends on where (s)he is seated, the intensity of the talker's voice, and the amount of background noise that is present (Larsen & Blair, 2008). The variable nature of classroom environments and the current lack of consistency in classroom design have led to questions about how best to overcome these problems. There are some primary issues that need to be considered in classroom amplification.

First, in 2006, the Acoustical Society of America (as cited by Lubman & Sutherland, 2008)) took the position that classroom amplification systems may do more harm than good if they are not installed properly or if the room is too reverberant. We hypothesize that classroom amplification is appropriate in every classroom and in every setting where children are being educated. Reverberation may make amplification less than ideal, but even in a poor acoustic environment, children are likely to benefit from a direct signal and an increased SNR. However, this hypothesis requires further investigation.

Second, in a position statement, the American Speech-Language-Hearing Association (2005) recommends +15 dB SNR at the child's ear; however, Larsen and Blair (2008) found that the average SNR was +13 dB. While the ASHA guideline is ideal, we suggest that every classroom should have at least a +12 SNR at every place that a student will be expected to hear. In our anecdotal observations of a variety of classrooms in several schools, we noticed what appeared to be an inconsistency in the level of SNR and an inconsistency in the number of teachers who were actually using the systems on a consistent basis at an optimal level. In order to determine if our observations were accurate, we sought permission to collect data in one school in our local school district.

We sought to obtain answers to the following research questions:

1. Do amplification systems in every classroom and grade level provide the same average levels of amplification?
2. Is the average SNR in each classroom at or above a +12 dB?
3. Will placing loudspeakers within 8 feet above a student's head in a reverberant classroom improve the average SNR at the student's ear?

## Method

### School

A building in a rural northeastern Utah town was used as the data collection site. This school was selected because it is the oldest school in the district and has been the site of numerous expansions and renovations over its 150-year history. The measurements were taken in the morning because this was the time when the most active teaching and learning was occurring in the building. The school was fit with classroom amplification two years before this research. The company from whom the equipment was purchased also installed all of the systems. Based on information obtained from the companies who sell classroom amplification equipment, the majority of schools use the company from whom the equipment is purchased to install their systems, and most systems are installed in empty classrooms. The installers set the equipment at a level that "sounds appropriate" to them. If this is the method used most frequently, variability in amplification levels is expected among classrooms. In order to determine if each classroom was amplified at an appropriate level, measurements were conducted in each classroom in the school building, starting with first grade and ending with fifth grade.

### Equipment

A Larsen-Davis Sound Level Meter (type I, 800b) was used for the measurements taken in each classroom. The measurements were taken at a central location about half way between the closest and most distant student in each classroom. We also used a half-inch microphone and preamplifier (Sennheiser) connected to a laptop computer with SIA SMaart software to measure the impulse response of one class in some detail. The impulse response is measured by playing a pseudo-random noise signal that contains a broad frequency spectrum to stimulate the acoustic properties of the room. Once the room is excited with the pseudo-random noise, the response of the room is recorded. Then, offline, the pseudo-random noise is subtracted from the recording so that only the acoustic response of the room, or impulse response, remains. From the impulse response of the room, several important acoustic factors can be obtained, including the reverberation time (RT) of the room.

Each classroom was fit with a classroom amplification system (Audio Enhancement Infrared Wireless Model CAE-50W) that had four loudspeakers placed in the ceiling tiles of the room. In some classrooms, this was not possible because the room had no hanging ceiling and, therefore, no space to place the loudspeaker. In these classrooms, the loudspeakers were placed high on the classroom walls at a height of approximately 9 feet and angled down toward the center of the classroom.

### Procedure

Measurements were taken in each of the 14 classrooms approximately half way between the closest and most distant students from the teacher in the center of the room. The measurements were taken at the approximate ear level of an average student in the class while the teacher was presenting information to the class. Teachers were asked to use the amplification system and then to talk while the system was turned off. We took measurements every 15 seconds for a period of 10 minutes (i.e., 5 minutes with the system on and 5 minutes with the system off) in each classroom and then averaged the sound pressure level in dBA for both amplified and unamplified conditions. In each classroom, the predominant source of sound was the teacher during our measurements. Measurements were obtained with the sound level meter set to the slow integration setting and on the A-weighting scale.

After completing the measurement of all the classrooms, we returned to a first grade classroom for additional testing. This particular room was of interest because of its construction. The ceilings were at a height of 8 feet for half the room and up to 15 feet for the other half. The teacher taught in the section of the room with the lower ceiling. During the observation, nine students gave a brief report to the class. We measured the level of the students' voices compared to the background noise. The speakers were then lowered to a level that was 7 feet- 4 inches off the floor.

Measurements of loudspeaker output and reverberation times were repeated. Lowering the speakers could produce feedback, but the speakers would be in closer proximity to the students and place them within the direct field of the loudspeaker. This means that the students would be receiving the direct signal from the loudspeaker at a more intense level than the level of reverberation in the room.

The point at which the intensity of the direct signal is equal to the intensity of the reverberation in the room is called the critical distance. This critical distance differs for each loudspeaker and each classroom, but can usually be expected to be 6 to 8 feet from the loudspeaker. This distance can be calculated when the size of a room and the reverberation time within that room is known. This particular classroom was measured and the reverberation time was also measured to allow the critical distance to be estimated. When using classroom amplification, placement of a child within the critical distance is ideal because the direct speech will be clearer and more easily comprehended than speech within the reverberant field beyond the critical distance (Crandell & Smaldino, 2000; Peutz, 1971). For this particular room, moving the loudspeaker to 7 feet- 4 inches above the children's heads allowed us to make two measurements with children within and outside of the critical distance of the loudspeaker.

## Results

Table 1 illustrates the amplified and unamplified results we obtained for each classroom. As can be seen, the average SNR over all the classrooms was almost 13 dBA with a range from +5 to +23 dBA. Some of the teachers reported that they were not sure if the microphone helped very much, while others reported that they had a "loud teacher voice" and that the children probably heard as well without the microphone as they did with it. It is possible that teachers who only demonstrated a 5 dB difference between the amplified and the unamplified conditions may not have noticed that much of an improvement in students being able to hear them. In contrast, teachers who obtained a 12 dB or better improvement in amplification all noticed a significant improvement between the unamplified and the amplified condition.

**Table 1.** The amplification data from 14 classrooms during instruction.

| Unamplified level | Amplified level | Difference | Grade Level |
|---|---|---|---|
| 60 dBA | 70 dBA | 10 dBA | 1st |
| 60 | 68 | 8 | 1st |
| 54 | 59 | 5 | 1st |
| 54 | 68 | 14 | 2nd |
| 49 | 64 | 15 | 2nd |
| 50 | 68 | 18 | 2nd |
| 49 | 72 | 23 | 3rd |
| 60 | 72 | 12 | 3rd |
| 55 | 68 | 13 | 3rd |
| 42 | 64 | 22 | 4th |
| 62 | 68 | 6 | 4th |
| 57 | 66 | 9 | 4th |
| 65 | 71 | 6 | 5th |
| 42 | 62 | 19 | 5th |
| | Average Difference | 13 dB | |
| | Range | 5 – 23 dB | |

### First Grade Classroom with Unusual Design

After collecting data for all the classes, one unusual first-grade classroom, as explained above, was examined in more detail. The measured reverberation time in this room ranged from .70 seconds in the section of the room that had 8 foot high ceilings and then increased to 1.4 seconds in the section in which the ceiling was 15 feet high. The first measurements taken in this room found that the teacher's voice was on average 8 dB more intense than the background noise. We asked the teacher if we could increase the classroom amplification so that it was 12 dB more intense than the background noise, to which he agreed. One month later, we returned to this room to conduct additional measurements. The teacher was now using an average level that was 15 dB louder than the average background noise. He reported that the students were more attentive and that his ability to communicate had improved. He was also using a pass-around microphone for the students during sharing time, where the average SNR for the children was approximately +10 dB. The students seemed to enjoy using the microphone during their presentations, and the teacher reported that more children were willing to participate when using the microphone. Table 2 illustrates the vocal intensity of the nine students during sharing time with the microphone compared with background noise during their presentations.

As was described earlier, one of the problems with this classroom was the unusual configuration of the ceiling. To examine if the acoustics could be improved, two of the speakers were lowered to 7 feet-4 inches (instead of 15 feet) and placed directly overhead. Lowering the speakers would effectively place all of the students in the direct sound field rather than in the distant sound field. The additional measurements revealed that, by lowering the speakers, another 2 dB in SNR advantage was gained. The reverberation time also changed from .68 to .64 seconds. Finally, this improvement was achieved without significant feedback from the amplification system, which can occur when the loudspeaker is placed in too close proximity to the microphone of the system.

## Discussion

The advantages of classroom amplification are well documented; however, as this research has shown, there are some adjustments that could be made to improve the benefits of these systems. One important issue would be to designate an individual

**Table 2.** Average intensity levels and signal-to-noise ratios during 2-½ minute student presentations with a hand held microphone.

| | Nine Students | Background Noise | Signal-to-Noise Ratio |
|---|---|---|---|
| | 61 dBA | 55 dBA | +6 |
| | 64 | 52 | +12 |
| | 66 | 55 | +11 |
| | 65 | 56 | +9 |
| | 63 | 57 | +6 |
| | 59 | 52 | +7 |
| | 68 | 56 | +12 |
| | 69 | 55 | +14 |
| | 66 | 57 | +9 |
| Average: | 64.5 | 55 | Difference: 9.5 |

in the school system that would actually go into each classroom on an annual basis and adjust the system so that the teachers' voice level was consistently at least 12 dB louder than the noise floor in the room during instructional periods. In this way, the individual differences in teachers' voices and classroom noise could be consistent across classrooms. Another issue that could be addressed would be the positioning of the speaker so that all students are in the direct sound field. It would not be difficult to design speakers so that they could be attractive and hang no more than 8 feet over the floor. There has been a tendency of manufacturers to go to a one- or two-speaker system, which is placed at the front of the room. While this arrangement is certainly convenient, all students will not be in the direct sound field. A potential solution would be to hang speakers from the ceiling to make sure that all children are in the direct sound field. Another advantage of placing the speakers in the ceiling (8 feet over the floor) is that the students' bodies will diffuse the sound and both the carpet and the bodies will absorb some of the sound.

The effects achieved in one classroom by lowering the loudspeaker to be closer to the students demonstrated both a gain in intensity and a very modest reduction in reverberation. It is hypothesized that bringing children into the direct field of the loudspeaker would result in increased speech recognition abilities and less stressful listening conditions for the students. We also believe this would benefit those with hearing loss, those whose first language is not English, and those with other learning problems. Of course, additional research needs to be done to demonstrate the advantages and feasibility for suggesting lowering the loudspeakers to bring children within the critical distance.

### Limitations of this Research

The ability to generalize from these conclusions is limited because we only examined one building in one school district. We also only analyzed one classroom in detail and cannot suggest that our findings are similar to what others would find. However, our experience and observation suggest that the findings of this research warrant further investigation. We hope that such investigation will lead to better use of classroom amplification to improve the learning environment for all children in all schools.

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