EDUCATIONAL SERVICE DISTRICT 112

WHITE PAPER:

CLASSROOM AMPLIFICATION SYSTEMS

Understanding and overcoming the acoustical barriers to learning

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Executive Summary

While a classroom amplification system is not a matter of technology integration or technology literacy, it clearly represents a technology solution that provides an ***optimal learning condition*** in the classroom. There is an abundance of independent research that shows the need for amplification in the K-12 classroom, both for hearing-impaired students and students with normal hearing. That research is clear, consistent, and conclusive.

This paper will provide information about the need for classroom amplification, and readers will develop an understanding of why this solution is so critical in a learning environment. Specific questions that are addressed include:

- What does the research say about classroom acoustics and their impact on the students' sound perception, attention span, and student achievement?
- What are the three acoustical barriers to sound recognition and speech perception of the students?
- What is *noise,* and what is the significance of the *Signal to Noise Ratio* in a classroom?
- What are the classroom acoustic guidelines that are recommended by the American Speech-Language-Hearing Association?
- How can classroom sound amplification systems help overcome the acoustical barriers in the classroom?
- What are some of the various solutions available that can overcome poor acoustics?

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Introduction

Classrooms are learning environments where people communicate by talking and listening. Yet, typical classrooms have been shown to have acoustical characteristics that are detrimental to students with normal hearing, as well as to students with a hearing loss or learning difficulties.

In a paper entitled *Classroom Amplification Technology: Theory and Practice* (Smaldino and Crandell, 2000), the authors point out that listening is the primary mode of learning in the classroom. Students are listening to the teacher and to each other. As a matter of fact, it is estimated that students are listening about 45% of the school day. Listening to announcements, school bells, friends, videotapes; and classmates are all listening exercises in which students are engaged.

Most teachers are verbal instructors. Even though they may combine verbal cues with their lessons, speech perception is critical in understanding the dialog about those cues. Yet teachers are not the only ones speaking in classrooms. Students are also contributing communicators as they listen, ask questions, answer questions, and discuss the lessons.

In the same article, Smaldino and Crandell (2000) cite four classroom characteristics as reasons to study classroom acoustics:

1. The volume and nature of the teacher's delivery;
2. The presence of excessive background noise;
3. The reverberation of sound;
4. Distance as a multiplier of noise.

In addition, they have added two student attributes to the list of reasons to investigate this topic:

1. The hearing ability of the students;
2. The linguistic experience of the students.

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What is noise?

Ambient noise in a classroom is defined as *any unwanted or uninvited sound that interferes with a student's reception of speech.* There are three sources of ambient noise in a classroom. (Ching & McPherson, 2005)

Classroom Noise
Classroom noise is generated from within the four classroom walls, and includes the sliding of tables and chairs, computer fans and printer engines, buzzing overhead lights, the passing out of papers, and other general noises made by the students. The most dominant uninvited noise in the classroom, however, is caused by the HVAC systems; they are difficult to quiet in new schools, and are very expensive to retrofit in older, renovated buildings.

Internal Noise
Internal noise has its origin within the school building, but outside of the classroom. Hallways, music rooms, cafeterias and adjacent rooms are good examples of this type of noise.

External Noise
External noise refers to any noise that is generated from outside the building. Sounds that come from playgrounds, traffic, buses lining up, airplanes and construction are all considered to be external noise.

In the midst of all of the uninvited noise, the learning must go on, and the speaker (most often the teacher, but sometimes the students) must compete with these other kinds of noises in order to be heard. The relationship between the speaker's voice (known as the **signal**) and all of these background sounds (the **noise**) is known as the **Signal to Noise Ratio.**

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Signal to Noise Ratio

It is the **Signal to Noise Ratio (SNR)** that is considered to be the most crucial requirement for effective communication in a classroom. Most researchers in this field that write about their findings recommend a classroom noise level that does not exceed 35 dBA. (Crandell, 1991; Finitzo, 1988) The American Speech, Language and Hearing Association (ASHA) is even more stringent in

their recommendation, calling for a maximum noise level of 30 dBA. However, studies also show that *the typical classroom has noise levels that range from 41 to 51 dBA.* (Bess, Sinclair & Riggs, 1984; Crandell & Smaldino, 1994)

Keep in mind that a speaker's voice must overcome the ambient noise in order for him/her to be heard. Most researchers in this field, as well as the ASHA, recommend that a speaker's voice should be +15 dBA more than the dBA of the background noise. For teachers who teach all day in noise cluttered classrooms, and for students who have quiet or muffled voices, this can be an unattainable standard. Not surprisingly, *most classrooms typically fall short of the recommended SNR of +15, and have SNR's that range from -7 dBA to +4dBA's.*

Creating a learning environment with a favorable Signal to Noise Ratio is especially critical for children in the younger grades who are engaged in many activities that focus on speech and sound recognition. These inexperienced learners don't have the ability that adults do to adjust their hearing in unfavorable listening conditions, and they typically don't acquire that kind of maturity until they are 13-15 years old. (McSporran, 1997)

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Reverberation

The second obstacle to sound perception in a classroom is **reverberation,** which is defined as *the persistence of sound within an enclosed area as it is reflected off of hard surfaces.* Reverberation time (RT) is the time it takes for sound to decay by 60 dB from its original intensity.

The significance of excessive reverberation is that it has a marked negative effect on speech perception by smearing or masking sound. Again, young learners are most affected by this classroom acoustical factor. Specifically, the stronger, lower frequency vowels will mask the weaker, high frequency consonants that are required for speech intelligibility, making it more difficult for the inexperienced learner to perceive the sounds of speech.

The ASHA, along with researchers in this field, recommend that classroom reverberation times should not exceed .4 seconds. (ASHA, 1995; Finitzo-Hieber & Tillman, 1978) *However, the RT in most classrooms ranges from .4 to 1.25 seconds.* (Crandell, 1991; Crandell & Smaldino, 1994)

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Distance

Distance from the speaker is the third acoustical obstacle to sound perception in the classroom, and it's important to remember that the teacher is not always the speaker in the classroom. Keeping that in mind that students need to hear each other as they dialog and respond to each other, the research shows that:

- Students should be within six feet of the speaker.
- Distance affects both noise and reverberation time.
- Speech is more difficult to recognize in the back of the room.
- This affects students with normal hearing *and* a hearing loss.

(ASHA, 2005)

Other Student Factors

The discussion of this paper so far has centered on the acoustical barriers to sound perception in the classroom. However, students come to school with some of their own, personal challenges caused by hearing loss, or lack of experience due to age and maturity. The next portion of this paper will address those student characteristics.

The Student's Hearing *as a factor...*
Approximately 43% of all primary students suffer from a temporary hearing loss on any given day and will fail a pure-tone screening at 15dB and/or an immittance screening. (Flexer, Wray & Ireland, 1989) They are at greatest risk in noisy classrooms, seated far away from the teacher.

The Student's Experience *as a factor...*
A young learner's developing speech and language system requires better acoustical conditions than an adult with a rich background of life experiences. When a young learner can not hear a part of the spoken word, they don't have the life experiences to draw upon to compensate for the speech that they missed.

For example, a teacher might say:

An insect has three body sections, three pairs of legs, antennae and wings. Draw a picture of an insect.

But a young learner might hear:

An --sect has --ree bo-y -ections, ---ee -airs of -egs, ante--- and wi---. –aw a pi------ of an –sect.

If an adult misses a portion of this sentence, it's likely that their understanding of the content won't be affected. They know enough about the characteristics of insects to fill in the blanks. However, young students may be learning about insects for the first time, and as a result, may not know how to carry out the instructions of drawing an insect.

The linguistic, cognitive and social knowledge that is required in the listening process influences the child's ability to make meaning from what is heard. Poor acoustic conditions will cause a child to spend more time and energy on deciphering the message than on its interpretation and meaning. (McSporran, 1997)

The research clearly states that a classroom with poor listening conditions is even detrimental to children with **normal hearing.** For example, the findings from a 1978 study showed that students in a fairly good acoustical space were only able to recognize 71% of the test stimuli, and that fell sharply to 30% in a poorer, but typical, classroom listening environment. (Finitzo-Hieber and Tillman, 1978)

The research also supports the notion that typical mainstream classroom acoustical conditions make it difficult for children with any of the following:

- Learning difficulties;
- Language disorders;
- Central auditory processing disorders;
- Phonological problems;
- English as a second language;
- History of middle ear problems;
- Other hearing losses.

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Solutions to Overcome Acoustical Barriers

Several attempts have been (and continue to be) made to overcome the three acoustical barriers in classrooms:

The ASHA's Recommended Acoustical Standards
Districts that are building new schools or renovating older ones should consider acoustical conditions of the environment as they design and redesign their learning environments. For instance, a noise analysis should be conducted at the time of selecting a site for a new school. Proximity to traffic, airports and other noisy environments should be avoided. But that's not always possible or realistic.

Structural Modifications and Sound Treatments
Physical changes can greatly reduce the noise factors in the classroom, and include modifications to the floors, walls, ceiling and windows. Strategically placed bookshelves, as well as portable chalkboards and bulletin boards placed at nonparallel angles to the walls, are also effective ways to reduce RT. The use of double-paned windows will reduce the noise coming in from outside, and drapes are the most effective treatments for windows.

The use of sound treatment materials, such as carpeting and acoustical ceiling tiles, can assist greatly in absorbing middle and high frequency sounds, reducing the reverberation in the classroom. Because the floor and ceiling take up about 60% of the surface area, those two modifications can greatly improve the acoustics. Other sound-absorbing treatments include cork bulletin boards and children's artwork made of absorbent materials.

Organization and Management of Students
Working with students in small groups during lessons is a way to reduce the distance factor and to improve acoustical conditions, but this of course, can not always be done.

Developing Listening Skills in Young Children
Children must be taught to listen effectively in order to receive and interpret a meaningful audio signal.

Technology for Improving the SNR
Sound amplification systems can be used to eliminate the noise and distance acoustical barriers, therefore creating a favorable *Signal to Noise Ratio.*

The remaining portion of this paper will focus on the use of technology in overcoming the acoustical barriers in the classroom.

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Sound Amplification In the Classroom

While sound amplification does not eliminate the reverberation of sound, it does help to improve the Signal-to Noise Ratio, and help overcome acoustical barriers. Basically, there are two types of sound amplification for learning environments:

Sound-Field (SF) Amplification System
The teacher wears a mic and a transmitter, and his/her voice is sent from the transmitter to an amplifier that is connected to a set of classroom speakers. This can also be connected to another sound source such as a vcr. All students benefit from the use of sound-field amplification as the level of the teacher's voice over the ambient noise is increased. In general, it is a cost-effective solution for the classroom.

The Personal FM System
In some cases, general sound amplification will not be enough to eliminate the acoustical barriers for children who are suffering from otitis media or another temporary or mild hearing loss. A special hearing device, also known as an ***assisted listening device,*** may also be needed by some students. In these cases, a personal FM system utilizes a teacher microphone that sends the sound through a transmitter that he/she is probably wearing. Like a SF amplification system, it can also be connected to a television, tape recorder or radio. The listener wears a receiver which can be attached to earphones, or coupled directly to a hearing instrument. These are typically prescribed for students with hearing loss, and can be quite costly.

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Research That Has Been Reported

There is an abundance of research that provides empirical evidence that the use of sound amplification in the classroom leads to increased student achievement, increased student motivation, and a decrease in teacher absences.

THE MARRS STUDY
The *Mainstream Amplification Resource Room Study (MARRS)* was the first investigation reported on the use of sound field amplification in the U.S., and at the time of authoring this paper, is the only study noted on the U.S. Department of Education's clearinghouse web site for what works in schools. This 1984 study focused on elementary children in grades K-6 with normal learning potential and a minimal hearing loss, but who were behind academically by six months or

more. Half of the students were placed in classrooms with sound amplification, and the other half was given extra teaching support. The results of the study showed that the students in the amplified classrooms achieved significantly improved reading scores that were equal to or greater than the other children.

The specific findings were reported at intervals throughout the study:

Immediate (First Days or Weeks)

- The quality of instruction improved as students were more engaged and responsive to the lessons, regardless of class size, background noise, seat location, or dealing with a mild hearing loss.
- The improved student attention, particularly with A.D.D. students, resulted in better classroom management, less student distractions, less need to repeat instructions, and higher test scores on listening tests.
- The teacher experienced less stress from having to raise his/her voice, and the students expended less energy trying to hear the speaker.
- Teacher absences due to vocal strain were reduced from 15% to 2-3% in one year.

Short Range (Several Weeks)

- Classroom management improved, as indicated by a reduction in discipline problems, an increase in time on task, and less time for taking tests.
- An increase of student motivation, participation and confidence was documented, as well.

Long Range (Months or Years)

- An improvement of reading and language test scores in the early months was reported, for all students at all levels.
- There were statistically significant gains in overall composite test scores within less than one full school year. And these gains have been sustained in research study periods for up to three years.
- Where classroom amplification has been introduced in grades K-6, the number of referrals to Special Education has been reduced by up to 43% over five year periods.

Other findings of the MARRS Study showed that it was the younger children that showed the greatest gains, and that the use of the equipment was also beneficial to non-target children and teachers.

OTHER STUDIES

The benefits of sound amplification in the classroom have been proven in other studies, as well.

McSporran (1997) cites three studies that were conducted on sound field amplification in the classroom.

- Blair, Myrup and Viewhweg reported their work in 1989 on three types of potential sound amplification.
- In the same year, Jones, Berg and Viehweg reported their study on the listening skills of Kindergarten students under close, distant and amplified conditions.
- And Neuss, Blair and Viehweg conducted an investigation on whether sound amplification in the classroom improves word recognition for hearing impairments in a background of noise.

McSporran shares that they all concluded in their reports that...

*"… **improved speech recognition scores** in quiet and noisy classrooms, for children with **normal hearing** as well as those with **minimal hearing loss, including hearing aid wearers** … and for children using English as a second language."*

Flexer conducted a study of 5-9 year olds and the efficiency and effectiveness of sound field amplification in the classroom. Out of that came a report in 1992 about the characteristics, selection and use of classroom systems. But his report showed...

"...higher achievement in the basic skills of 5-9 year old children in amplified classrooms, compared to those in similar, unamplified classrooms. Improvements in children's attention and participatory behavior … were also noted."

And while most studies have been conducted with primary children, Berg, Batemen and Viehweg presented their findings in a paper at the annual convention of the American Speech-Language-Hearing Association in 1989, citing their study and findings of sound field amplification in junior high classrooms, and reported …

"...improved attention and understanding (in 11-14 year olds) as well as improved ease of listening and teaching."

In a study of two 9th-12th grade classrooms with learning disabled students, a sound amplification system was installed for a period of three months (DiSarno, Schowalter and Grassa, 2002). Results of the study showed...

"...a significant improvement of students' listening and academic behaviors after twelve weeks, as measured by two evaluators. The main benefit of sound-field amplification cited in this study was an increase in the teacher's ability to get and maintain students' attention."

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Teacher and Student Feedback

Laurie Allen, an educational audiologist in Dubuque, Iowa, surveyed fifteen elementary teachers and their 334 students in order to measure the benefits of sound amplification in their eight classrooms, and to support its continued and increased use in the schools. By asking the teachers 15 questions, she documented the following characteristics that teachers used to describe their amplified learning environments, and shared them with the ASHA in 1994:

- Improved learning environment
- Decreased need to repeat instructions
- Improved attention span
- Gave them better control
- Decreased transition time
- Increased ability to learn
- Ease of use
- Decreased fatigue

As she surveyed 334 students in grades 1-6, she learned that:

- 93% liked it when the teacher used the system.
- 84% said that the system made speech clearer.
- 95% said it was easier to hear the teacher when the speakers were on.
- 88% liked using the student pass-around mic.
- 87% said they do better when the speakers are on.

(Peters-Johnson, 1995)

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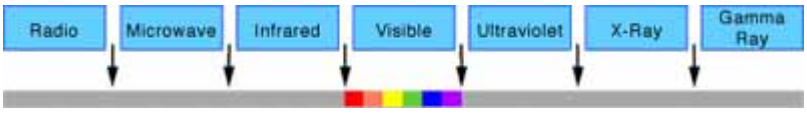
Technology Solutions For Sound Amplification

The research shows that the acoustical barriers to speech recognition and sound perception can be overcome with the use of sound field amplification in the classroom. This section of the paper will share information on solutions that vary in features and pricing. By no means are these the only sound amplification systems available on the market; rather, these are the solutions that this author has knowledge of and experience with.

INFRARED vs. RADIO-FREQUENCY SYSTEMS

The dominant technology in sound amplification systems is infrared (IR). Infrared light is also known as plain-old "heat." The basic premise at work in an IR system is the use of light to carry signals between a transmitter and the device it's directing. Infrared light is in the invisible portion of the electromagnetic spectrum.



An IR transmitter sends out pulses of infrared light that represent specific binary codes, and the IR receiver, which usually sits on the front of the device where it can easily see the signal coming in from the microphone's transmitter, decodes the pulses of light into data that the system can understand. There are times when IR transmitters only work when you're pointing them directly at the receiver on the controlled device, while others work when you're pointing them in the general vicinity of the receiver. This has to do with the strength of the transmitting LED. A remote with more than one LED and/or a particularly powerful LED produces a stronger, broader signal.

Instead of sending out light signals, a radio-frequency (RF) transmitter sends radio waves, and a radio receiver on the controlled device receives the signal and decodes it. The problem with RF remotes is the sheer number of radio signals flying through the air at any given time. Cell phones, walkie-talkies, WiFi setups and cordless phones are all transmitting radio signals at varying frequencies. The greatest advantage to radio-frequency remotes is their range; they can transmit up to 100 feet from the receiver. However, radio signals can go through walls, creating a problem when RF systems are installed in adjacent classrooms. In these cases, the systems in the adjacent classrooms need to be configured with different frequencies.

SOUND AMPLIFICATION SOLUTIONS

Sound amplification systems for classrooms are like other technology solutions for learning, in that there is a wide range of options available to schools. For those schools that wish to provide a sound amplification solution in classrooms but are on very tight budgets, they may wish to consider Califone's PA-300 UHF system, or their PI30-SYS system.

Califone PA-300UHF System (Radio Frequency)

I:\Technology and Research\Sound Amp

This is a cost-effective solution for classrooms. It is simple to use and is powerful for voice amplification and multimedia presentations. Wireless connectivity allows the use of additional speakers which can easily and quickly be added for greater audience coverage. The system includes:

- Amplified 30-watt speaker with built-in receiver and lots of inputs
- Choice of a wireless handheld, lapel, collar or headset mic
- Volume control on the belt pack for the teacher
- Portable tripod and mounting bracket
- Infrared remote with Mute and Volume control
- Protective hard case with form-fitted foam

Califone PI30-IRSYS System (Infrared)

I:\Technology and Research\Sound Amp

The Infrared Classroom System delivers all of the benefits of sound field amplification (without any interference between classrooms) for greater coverage and reception, with the added benefits of two non-powered "array" speakers. This solution is very easy to install, and offers several advantages for teachers and students:

- Targets the sound pattern directly at the audience, not randomly bouncing the sound off walls like canned ceiling speakers
- Evenly distributes volume so level is the same at front/rear
- Volume controls on the belt pack that the teacher wears
- Option of using the collar mic or handheld mic, or both
- Two sensors in the receiver expands coverage area

FrontRowPro (Infrared)

I:\Technology and Research\Sound Amp

This wireless active learning system is easy to operate and is designed to clarify the teacher's voice for all students. Its lightweight wireless pendant microphone is comfortable and produces quality sound. The teacher can mute his/her voice with the touch of a button on the pendant. This system integrates nicely with other audio-visual equipment. It includes:

- Two built-in microphones in the pendant
- Base station with two channels
- Choice of ceiling-mounted or wall-mounted speakers
- Optional student handheld microphone (additional charge)
- Fail-safe battery charging

LightSPEED's REDCAT (Infrared)

I:\Technology and Research\Sound Amp

The REDCAT is an all-in-one system that works right out of the box and requires no installation. This system can be mounted on the wall like a picture frame, or placed on a bookshelf or desktop. It distributes sound evenly throughout the classroom and is specifically engineered to deliver outstanding voice intelligibility.

Some of its features include:

- Flat panel speaker technology
- Two microphone channels
- Wireless LT-71 LightMic w/transmitter
- Auxiliary inputs and outputs
- 8-band graphic equalizer
- Transmitter wall charger
- Integrated infrared sensor
- Multiple microphone options
- Reflected IR light ensures constant reception

LightSPEED's 820iR System (Infrared)

I:\Technology and Research\Sound Amp

The 820iR delivers the essential features necessary to amplify the speaker's voice in a standard classroom environment. This system is compact and affordable. Choose from a wide range of LightSPEED

speaker systems to ensure clear speech intelligibility for the entire classroom. It features:

- Infrared wireless technology
- Two microphone channels
- Wireless LT-71 LightMic w/transmitter
- Multiple speaker choices
- Two speaker inputs and outputs
- One output for personal FM system
- 8-band graphic equalizer
- Built-in transmitter charging jacks
- Quick-install IR sensor
- Ability to power up to 3 IR sensors
- Multiple microphone options

OTHER SOLUTIONS TO RESEARCH

Only a few of the sound amplification solutions have been presented in this paper, but others are available, and school districts that are exploring the potential of this classroom solution should research them. To learn more about them, use your favorite search engine for *classroom amplification system*.

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What to Look For

When exploring sound field amplification systems, it's important to identify the goal that you are trying to achieve. Are you trying to improve the Signal to Noise Ratio because your school is close to an airport? Do you need to overcome the distance factor in large classrooms and learning environments? Are you trying to improve classroom acoustics for your ESL students or students with mild or temporary hearing loss?

Once you determine your goal, consider your budget for this technology solution. There are a wide range of solutions available, and the more expensive ones have sound quality and features that the less expensive ones lack. Does your budget support the higher quality, more expensive solutions, or do your budget constraints require you to consider the entry-level solutions?

It's often difficult to know where to start with your investigation of products. Questions to ask the company representative might include:

- Is your solution an infrared or an RF system?
- How does your solution help to address the masking of the weaker, higher frequency sounds, such as consonant sounds?
- What kinds of elements interfere with your system? (Sunlight, other classrooms close-by that are using the same solution, etc.)

- What are the microphone options? (lapel, collar, pendant, headset, handheld) How many microphones can be used simultaneously?
- What are the microphone features? (mute button, comfort, sound quality when turning your head)
- How scalable or expandable is your product? In other words, what are some other ways that it can be used to amplify the signal in the classroom, such as vcr's, computers, televisions, personal FM systems, etc.)
- What are the speaker options? (single speaker, flat panel speaker, ceiling or wall mounted speakers, etc.)
- Considering the size and shape of the classrooms, are distributed speakers needed, or would they be overkill?
- What is the average life of batteries used in the microphones? What other considerations should be made about batteries?
- What is the warranty? And what does it cover?

The above questions could be turned into criteria that you use to compare each of the systems you investigate.

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Recommendation

All students benefit from being able to hear the speaker. The promise that technology brings in overcoming the acoustical barriers to speech recognition and sound perception is not only exciting; ***it has been proven.***

As districts build new schools, renovate older buildings, and equip classrooms with technology, sound amplification systems should be given the highest priority in creating learning environments where all students can reach their potential and achieve their learning goals.

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Summary

As schools strive to meet their mission of preparing tomorrow's workforce, it's easy to focus attention on creating digital communication networks, responding to state and federal mandates on technology integration in classrooms and technology literacy of our students, increasing student-to-computer ratios, designing data storage systems, and other high-tech educational topics. As we strive to meet some of our technology goals, it's imperative that we also consider the importance of using technology to create the *best learning conditions* for students.

This paper has presented information on the acoustical obstacles to sound perception in the classroom; the significance of students' hearing ability, language experience and cognitive development; the research on how sound amplification helps to overcome the acoustical barriers and its impact on student achievement; some technological solutions for sound amplification for classrooms; and assistance with a list of questions to ask a company representative who demonstrates their product.

*"In this day of educational reform, current concern about access to the curriculum, class size and standards of academic achievement in primary schools, it is difficult to ignore the argument that if children have difficulty listening to the teacher because of poor **classroom** acoustics, they are less likely to meet educational targets."*

McSporran, 1997

The research is clear...sound amplification is a cost effective way to improve classroom acoustics so that all students can learn to their potential.

On the Internet

This white paper can be downloaded from the Internet at **http://edtech.esd112.org/whitepapers/**

About the Author

Debbie Tschirgi is the Director of Educational Technology Programs at Educational Service District 112 in Vancouver, Washington. Every year, she convenes and facilitates a committee of technology decision-makers from school districts in the state of Washington for the purpose of comparing and evaluating classroom technology solutions, using well thought-out criteria. The goal of the committee is to select the solutions that will meet the needs of 85% of the educational organizations in the state of Washington, and that represent the *best value for the dollar.*

For more information about the ESD 112 Educational Technology Support Center, visit its web site at **http://edtech.esd112.org**

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