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Classroom Sound Field Amplification: An Introduction

ABSTRACT

Several factors, including lively students, noise from computers and air-handling equipment, poor classroom acoustics, outside sounds, and minor hearing difficulties, can have a significant impact on a student's ability to hear the instructor clearly.

Classroom sound field amplification systems have been successfully used to help students with hearing impairments. Recent research has demonstrated that even students with normal hearing ability benefit when these systems are used in their classrooms.

This paper describes the basic components of a sound field system and summarizes research related to the benefits that can be realized when classroom amplification is used to support the delivery of effective classroom instruction.

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What is a Classroom Sound Field System?

A typical classroom sound field system consists of ceiling mounted speakers, a small, lightweight wireless microphone worn by the instructor, one or more receivers, and an amplifier. Some systems also include a secondary wireless microphone that can be shared by the students when giving a presentation or reading aloud. The system amplifies the instructor's voice above ambient noise and evenly distributes the sound throughout the room. This creates what is called a "sound field." It enables instructors to be clearly heard by every student, without shouting or straining their voice.

Acoustical Barriers to Learning

Instructors must overcome numerous acoustical barriers to learning in order to effectively deliver instruction to their students. Problems include conditions in and around the classroom, student learning disabilities, and instructor vocal strain. Schools that have implemented classroom sound field systems have reported success in overcoming many of these obstacles. What follows is an overview of the problems that sound field amplification systems are designed to address.

Problem 1 – The Classroom Sound Environment

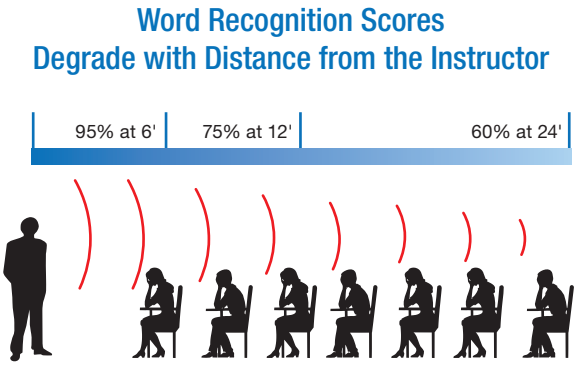
Many of the obstacles that interfere with a student's ability to hear the instructor stem from problems with the classroom sound environment. When noise levels in the classroom reach an unacceptable level, it is usually due to one or more of the following causes:

Instructors must overcome numerous acoustical barriers to learning in order to effectively deliver instruction.

Poor Classroom Acoustics: One of the most important things to consider in classroom design is acoustical performance. Hard flat surfaces in the classroom, such as floors, walls, whiteboards, and ceilings promote echo, which inhibits speech perception.

Research indicates that background noise and reverberation can adversely affect learning, especially for young children.[1, 2] It is more difficult for younger students to hear individual sounds clearly, as when learning to read and spell, and their concentration is also compromised. Poor classroom acoustics create an especially challenging educational barrier for those children who have hearing loss, speech impairments, or learning disabilities, and whose native language differs from the teaching language.

A 1999 study[2] on classroom acoustics measured noise levels in 94 unoccupied classrooms. The study concluded that 91 of them, or 97 percent, exceeded the recommended acoustical standards. In 2002, the Acoustical Society of America approved ANSI/ASA S12.60-2002, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools. The standard sets specific criteria for maximum background noise and reverberation and is consistent with long-standing recommendations for good practice in acoustical design.



Studies show that spoken word recognition scores decrease systematically as the distance from the speaker to the listener increased.

Noise Sources Within the Classroom: Classroom ambient noise can be caused by students talking or coughing, shoes scuffing on the floor, chairs creaking and being moved around, paper shuffling, pencil sharpeners, loud ventilation systems, and computer and projector cooling fans. This background noise can lead to instructor voice fatigue.

Distance From the Instructor: How far the student sits from the instructor has a measurable impact on the student's ability to hear and understand what the instructor is saying. Studies show that students should be no more than six feet from the instructor for maximum speech intelligibility.[3] Unfortunately, achieving this distance for all students given typical class sizes is not practical.

One study looked at a group of children, ages 5 to 14, in an acoustically good classroom. Researchers found that spoken word recognition scores decreased systematically as the distance from the speaker to the listener increased. While students at a distance of 6 feet from the instructor achieved scores of 95 percent, the scores dropped to 60 percent for those students seated 24 feet away.[4]

Noise Sources Outside of the Classroom: Sources of noise outside the classroom can include traffic, aircraft, playgrounds, construction, lawnmowers, and noise produced in other parts of the building, such as students in hallways, band practice, and impact noise from the room above. Occasional isolated noise from outside the classrom can cause a short-term disruption to communication, however, constant noise has a greater negative impact on speech intelligibility.

Problem 2 – Student Listening Difficulties

Estimates indicate that school-age children spend up to 75% of the school day engaged in listening activities.[5] Unlike adults, whose listening abilities and skills have fully matured, young children require optimal conditions for hearing and comprehension. The brain's auditory network is not fully functional until about the age of 15.[1] Children do not cognitively process what they hear the same way adults do. For children, the instructor's voice needs to be at least 15 decibels louder than the background noise in the classroom.[6] This decibel difference is called the Signal-to-Noise Ratio, SNR. Comparatively, adults only require an SNR of 4 to 6 decibels. Research also shows that students learning English as a second language need a greater SNR than those whose native language is English.[7]

Unlike background noise which remains relatively constant around a room, the sound of the instructor's voice varies greatly depending on where that instructor is located and where the SNR is being measured.[7] This is because sound decreases over distance; specifically it drops 6 decibels for every doubling of distance. For example, an instructor speaking at a 60 decibel level 3 feet out into the front of the classroom, will be heard at 54 decibels 6 feet into the room; 48 decibels 12 feet into the room and so on. Since the background noise level remains essentially the same, this decline

For example, an instructor 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.

A student's hearing and experience affect their ability to understand what is said.

in the instructor's voice means that the SNR declines the further back in the room the student sits. At some point, that SNR will drop below +15 decibels, preventing some students from hearing what the instructor is saying.

Creating a learning environment with a favorable SNR is especially critical for children in the earlier grades. These students are often engaged in activities that specifically focus on speech and sound recognition. Young, inexperienced learners have not yet developed the ability that adults have to adjust their hearing in noisy conditions that are unfavorable to listening, and they won't typically have that ability until they are 13 to 15 years old (see sidebar).[8]

How Many Students Have Trouble Hearing?: The Mainstream Amplification Resource Room Study, commonly referred to as the MARRS Project, was a study involving repeated observations over a three-year period conducted in the Wabash and Ohio Valley schools in southern Illinois.[9, 10, 11, 12, 13] Data obtained by the MARRS Project revealed that 20% or more of the current school population had academic difficulties coexisting with minimal hearing loss. Approximately 43% of K-12 students suffer from temporary hearing loss on any given day and would fail a pure-tone screening at 15 dB hearing level and/or an immittance screening that checks for fluid buildup behind the eardrum, a common childhood ear condition caused by ear infections.[14] When placed in noisy classrooms or seated far away from the instructor, these students are at greatest risk of not hearing what is being said.

According to the MARRS study, the students who would benefit from classroom amplification include those who are:

- under the age of 15
- sitting in the back of the class and may miss up to 30 percent of what the instructor says
- struggling academically
- in a noisy classroom environment
- in a team teaching environment
- learning under a soft-spoken instructor
- learning disabled
- learning English as a second language

Problem 3 – Instructor Vocal Strain

Vocal strain is inevitable for instructors who have to teach all day in noise cluttered classrooms, raising their voice in order to be heard and maintain order. The learning must go on, in spite of the noise. Instructors frequently complain about hoarseness, pain, and fatigue when speaking, as well as temporary voice loss.[15, 16]

Even in classrooms with relatively low noise levels, instructors must project their voices to be heard by all students. Often, instructors are forced to project their voices

well above a natural and healthy level. The result is higher than average throat and voice problems.

Research indicates that students typically increase their attention-to-task and show improved compliance when the instructor is in close physical proximity.[17] Close physical proximity is impossible to maintain for every student in the classroom, even more so when infectious diseases are going around. When an instructor is forced to repeatedly redirect students, often using a raised voice, it adds to instructor vocal strain and heightens the tension and anxiety among the students in the class. It is well known that some childrens' and young adults' response to a loud, forceful command can be opposite to the desired behavior. A natural conversational voice level generally results in the most favorable response.

Components of a Sound Field System

A classroom sound field system consists of a wireless microphone, receiver, amplifier, and speakers. The instructor's voice is picked up by the microphone and transmitted to a specialized receiver, which passes the signal on to an amplifier that sends it to speakers strategically placed in the classroom.

Some of the components of a sound field system. Other components include speakers and a mixer/amplifier.

The primary purpose of the system is to ensure that the instructor's voice and program audio are clearly audible above the background sounds at all instructional locations within the room. Research has shown that in the average classroom, the instructor's voice usually arrives at the ears of the students at a level only 6 dB or so above the background sounds.[18] The goal of the sound field system is to amplify the instructor's voice to approximately 15 dB above the noise level of the classroom, enabling every student to hear as if the instructor is standing nearby.

An overview of each of the system components:

Microphone: For best results, the instructor microphone should be lightweight to be worn on a lanyard around the neck or clipped to the clothing. Easy to use controls for volume, mute, and power give the instructor ultimate control and the freedom to make adjustments while teaching. For team teaching or group discussions that include guest speakers or students, a handheld microphone allows others in the classroom to be heard. Wireless transmission is critical because microphone cables can get caught on desks and other objects and restrict the instructor's range of movement within the classroom. Additional features, such as inputs for a portable audio source and external boom or headset microphone, are desirable.

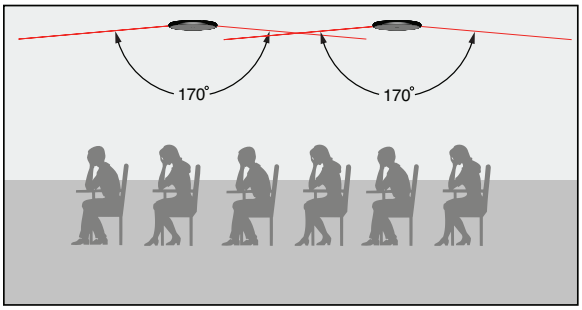
Receiver: The wireless receiver picks up the signal from one or more microphones in the classroom, converts the signal to analog audio, and supplies the audio to an amplifier. Two types of wireless transmission technology are used in sound field applications: Radio frequency (RF) and infrared (IR). See the sidebar for a comparison of the two technologies.

IR and RF Transmission Compared:

IR systems send the audio signal from the microphone to the receiver over an invisible beam of infrared light. RF systems use a radio transmission to send audio to the receiver. Each system has unique attributes that can influence the decision about which to use for a particular application.

IR transmission is line of sight, which allows the transmission to be localized to the room the person is speaking in. The instructor can exit one IR equipped classroom and enter another IR equipped classroom and have the advantage of a wireless mic in both rooms, while not having to be concerned about inadvertent open-mic conversations being heard while outside the classrooms. The downside of IR is that bright sunlight coming through windows, or bright artificial light can interfere with transmission. Also, IR transmission can be interrupted if the light path is blocked, such as when an instructor turns to face the whiteboard.

RF systems provide uninterrupted coverage within the range of the radio signal, typically about a 40x40 foot area. Instructors can be heard though the system speakers, whether they are facing the class in a brightly lit classroom, or talking into the whiteboard. But the instructor must be mindful to mute the mic to avoid broadcasting conversations when stepping out of the classroom and still within radio range. Modern RF mics operate in a license-free radio band. They employ digital radio technology that provides superior sound quality, feedback suppression, and transmitter-receiver channel pairing that prevents interference between mics in adjacent rooms, or interference with other nearby wireless RF devices.



For a typical classroom, use wide dispersion speakers for even coverage.

Amplifier: When selecting a sound field system, an amplifier with certain specialized features should be considered. The amplifier should offer professional-grade performance as well as power and space efficiency. Desirable features include compact size, multiple mounting options, and fanless, convection cooled operation. These valuable qualities make an amplifier ideal for low noise, restricted space, and low ventilation installations necessary in many classrooms. For maximum flexibility, an amplifier with sufficient power to handle small classrooms that require two to four speakers, as well as larger classrooms requiring six to eight speakers, should be considered.

Speakers: The purpose of the speakers in sound field applications is to accurately reproduce and evenly distribute the sound of the instructor's voice and program audio throughout the entire classroom to reach every student. For best results, specify speakers with uniform frequency response and wide coverage angle. The speakers must have a uniform response across the entire range of human speech and music, otherwise the program audio and instructor's voice will sound unnatural. In order to distribute sound evenly throughout the room with the minimum number of speakers, the optimum coverage angle for each speaker is 170 degrees. The speakers should be strategically placed to ensure the best coverage possible. Ceiling mounted speakers are recommended for best coverage; however, speakers can also be mounted on the walls around the room or at the room corners to suite unique room configurations.

Sound Field Systems Can Also Reinforce Program Audio

Sound field systems that save instructors' voices and allow students to be heard can also reinforce program audio. Program audio is the sound component of multimedia content originating from prerecorded or streaming sources such as DVDs or internet video streaming services. Program audio can be speech, music, sound effects, or any other sounds that make up the sound track of the video being shown to the class. Using multimedia content to enrich the curriculum helps instructors engage students so that students are more involved in their lessons and retain more information.

Even the best projectors and flat panel displays simply don't have audio systems capable of filling a classroom or lecture hall with sound that is intelligible throughout the room. The laws of physics make it hard to get big sound from small speakers shoehorned into ever more compact and thinner enclosures, firing sound downward toward the floor or backward toward a wall.

Program audio system design focuses more on sound distribution than amplification. The sound should be loud enough so that students can hear the program being played, but intelligible enough that students can make sense of what they are hearing. Intelligibility applies to speech. For music and other sounds, clarity is equally important. Sound amplification increases overall classroom sound levels and, if not carefully controlled, can produce uncomfortable volume, distortion, and interference with adjacent classrooms. For optimum balance between volume, speech intelligibility,

and clarity of other sounds (e.g., music), volume should be set to achieve an SNR of +15 dB, and a sound pressure level that is uniform to within ±2.5 dB throughout the listening area. [31]

Sound field system audio amplifiers have switched and auxiliary inputs that accommodate the audio from common classroom AV sources such as Blu-ray players, PCs, CATV tuners, streaming decoders and MP3 music players. While the video is displayed by the projector or flat panel display, the audio plays through the sound field system speakers. The sound field amplifier can perform automatic audio ducking and priority page muting, functions not easily accomplished with projector or flat panel speakers. Ducking automatically lowers the volume of one audio source when another source becomes active. This is useful if the instructor wishes to interject a comment about a currently playing AV program. When the instructor begins speaking into his/her mic, the program audio volume is lowered so that the instructor can talk "over" it. When the instructor stops talking, the program volume returns to normal. Priority page muting silences the sound field system speakers during public address announcements. This is a convenience for routine PA announcements, and an absolute necessity when the PA system is used as a school's emergency communications system or mass notification system.

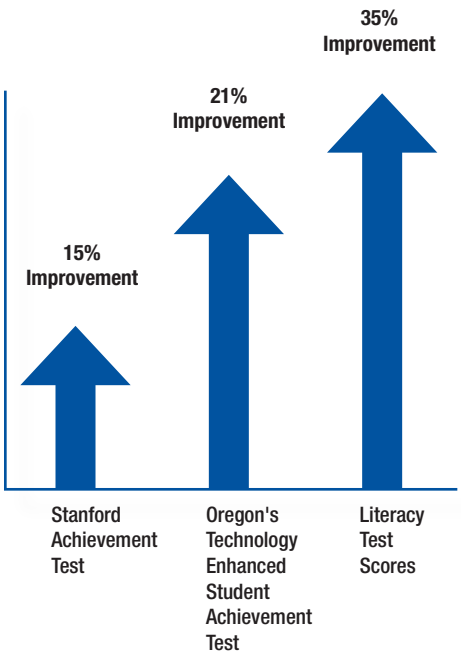
Benefits of Classroom Amplification

It is clear from the numerous studies that the use of a classroom amplification system results in improvements in the classroom environment, student academic achievement, and instructor health. The studies point to evidence of increased student attention, improved speech recognition, fewer distractions, and decreased off-task behavior. Schools that use classroom amplification technology have reported significant decreases in instructor absences due to voice fatigue and vocal strain. Classroom amplification is enthusiastically supported by students, parents, and school staff.

What follows is a summary of results measured by research projects. Unless otherwise noted, results are based on students with normal hearing ability.

Student Achievement: Educators and researchers have documented measurable results in student achievement in classrooms that use voice amplification.

- In Minnesota, the reading, math, and spelling skills of second grade students were tested three times over six months in one unamplified and one amplified classroom. Students in the amplified classroom posted significantly greater gains in reading and spelling. No significant difference in gains in math scores was measured between the two groups.[19]
- A study comparing the standardized test scores of first, third, fourth, and fifth grade students in unamplified and amplified classrooms in Oregon[20] found that:



Students in amplified classrooms achieve measurable increases in standardized test scores when compared with students in unamplified classrooms.
- 2004 Trost Amplification Study, Canby, OR

- ◊ First grade students in the amplified classroom scored an average of 35 percent higher on the Dynamic Indicators of Basic Early Literacy Skills – DIBELS than students in the unamplified classroom.
- ◊ The same group of first grade students in the amplified classroom scored an average of 21 percent higher on the Developmental Reading Assessment – DRA.
- ◊ Third grade students in amplified classrooms scored an average of 21 percent higher on Oregon's Technology Enhanced Student Achievement test and increased by an average of 32 words per minute in reading fluency.
- ◊ Fourth and fifth graders in amplified classrooms averaged 35 percent higher in words per minute on a reading fluency test than students in unamplified classrooms.

- Three Utah first grade classrooms, in which 85% of the children were Native American, were studied in 2002.[21] In the 5 years prior to the installation of classroom amplification systems, only 44 to 48 percent of the students scored at the basic level or above on the Utah State Core Reading Test. After seven months in amplified classrooms, 74 percent of the students in the study scored at the basic level or above.
- A study on the impact of classroom amplification systems on urban, at-risk fourth and fifth grade students in Utah[22] revealed that use of the technology successfully reversed a two-year downward trend in achievement test scores. The students in amplified classrooms scored 10 to 15 percent higher than students in unamplified classrooms on the Stanford Achievement Test, including reading, language, math, science, and social studies subtests.
- When researchers studied the impact of classroom amplification on kindergarten to third grade students in nine rural school districts in Ohio, they observed significantly higher test scores for children in amplified classrooms. Students with classroom amplification systems achieved higher scores on Iowa Test of Basic Skills subtests, with the greatest gains made by younger students.[23]
- The results of a multi-year study of Orange County Public School students in Florida showed that, on average, students in amplified classrooms scored 10 percent higher on the Florida Comprehensive Assessment Test than students in classrooms without classroom amplification.[16]
- When first grade students in four amplified classrooms were compared with students in four unamplified classrooms in Broward County, Florida, researchers noted that the students in amplified classrooms—especially bilingual and special education students—achieved greater literacy gains than students in unamplified classrooms.[25]

- Amplification systems were shown to have a significant impact on high achieving students in Colorado.[27] During the first year of amplification, students who had previously scored in the eighth and ninth stanines on the Colorado Student Achievement Test increased an average of 3.6 percentage points. According to the school's principal, the increased test scores were attributable to the introduction of classroom amplification, since no other significant changes were made to the school's instructional program or staff during that time period.
- Classroom amplification systems in southern Illinois schools were researched as part of the MARRS Project.[12, 13] Researchers reported that the number of students referred to special education in kindergarten to sixth grade dropped by 43 percent in amplified classrooms for students with and without hearing impairment.
- Similarly, after classroom amplification was used in 37 classrooms over an eight-month period in Wisconsin, special education referral rates in kindergarten to fifth grade decreased by almost 50 percent.[24]

Student Attentiveness: Research has shown that improved classroom environments are a direct result of the use of classroom amplification.

- In 2000, a study comparing unamplified and amplified first grade classrooms in Broward County Public Schools in Florida reported that instructors in amplified classrooms observed positive changes in students' attentiveness and classroom participation.[25]
- In a paper presented in 1989 at the annual convention of the American Speech-Language-Hearing Association, a team of researchers presented their findings on sound field amplification in junior high classrooms and reported, "...improved attention and understanding in 11 to 14 year olds, as well as improved ease of listening and teaching."[26]
- The MARRS Project found that the use of classroom amplification systems results in easier classroom management related to increased student attention, decreased discipline problems, less student distraction, and less need to repeat instructions.[12, 13]
- First grade instructors in Minnesota observed that their students were "less distracted, more attentive," and required "less repetition of directions" after the introduction of amplification systems into their classrooms.[27]
- A study of Ohio first grade students in amplified classrooms demonstrated increased participation, productivity, and on-task behaviors.[28]
- Students in amplified elementary classrooms in Iowa displayed an average of 17 percent increase in overall on-task behavior. Students were found to be less distracted in amplified classrooms and required less redirection by the instructor.[29]

Instructor Benefits: Classroom amplification systems allow instructors to spend the day speaking at a natural level, which significantly reduces voice strain and vocal fatigue.

- Instructors in amplified classrooms in Iowa reduced their absenteeism by 36 percent, which was directly related to a decrease in vocal health issues, such as voice, jaw, and throat problems.[30]
- Florida instructors in amplified classrooms reported decreased vocal strain and fatigue, and a multi-year study in Florida's Orange County Public Schools found a 25 percent decrease in instructor absenteeism in amplified classrooms.[2, 16]
- Researchers in the MARRS Project found that voice fatigue and instructor absences due to vocal strain in amplified classrooms decreased from 15 percent to an average of 2 to 3 percent in one year.[10, 13]
- Studies have also shown that instructors who use classroom amplification systems enjoy virtually unlimited freedom to move around the classroom while maintaining a stable acoustic environment. Wherever an instructor is located in relation to a student — even when the instructor's back is turned — students can hear clearly.[2, 12]

Conclusion

Classroom amplification systems help schools meet the needs of students and instructors by distributing sound throughout the room, effectively reducing the distance from the instructor's voice for every student, no matter where they are seated. Students in amplified classrooms receive maximum speech intelligibility and instructors experience a reduction in voice strain and freedom to move around the classroom.

Studies show that classroom amplification systems have a positive impact on student academic achievement, speech recognition, listening abilities, and instructor vocal health. The use of classroom amplification systems has also proven to help create an improved classroom environment, as indicated by fewer distractions, increased student attention, increased on-task behavior, and reduced instructor redirection.

When selecting classroom amplification equipment, it is important to understand the technology options available as well as the particular needs of the classrooms in which the systems will be installed. Selecting professional grade equipment from a manufacturer with experience in the education market will ensure the desired results are achieved.

Extron Electronics has extensive experience developing and delivering AV technology solutions for schools and universities.

For more information, visit www.extron.com/schools.

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