Audio for Distance Learning
Part 1 - Introduction

Why Sound Quality is Important

Popular media such as compact discs, movies, and music videos have helped to raise our standards for what qualifies as "good sound." Unfortunately, the sound quality in distance learning classrooms often leaves much to be desired. Poor sound quality will make it more difficult for students to understand the material being presented. It may also reduce their level of interest and participation in the class. Classroom audio systems that are poorly designed or implemented will inhibit interaction between students at different class sites, because they will not always be willing to make the effort required to overcome technology barriers which prevent them from being heard.

Complaints from instructors and students about classroom sound typically run along these lines:

"It sounds like the person speaking is at the bottom of a barrel."
"When someone talks, the first couple of words get cut off."
"We can't turn it up loud enough to hear without getting feedback or howling."
"When we talk, we hear an echo of our own words."

The technical and operational causes of these problems are rarely apparent to someone who does not have specific audio training. Fortunately, an understanding of just a few basic audio concepts can help the designer, installer, or user of a distance learning audio system to achieve very good sound quality in the classroom environment.

What it Takes to Make a Distance Learning Classroom Work

There are four main parts which make up a distance learning classroom:

- the classroom itself,
- an audio system,
- a video system, and
- a link to a transmission network.

This paper will focus on those variables in the classroom and the audio system which determine the quality and intelligibility (the ability to understand what is being said) of the sound that is transmitted to listeners at other classroom sites, and what must be done to control those variables.

While the choice of transmission medium - fiber optics, satellite, microwave, etc. - can have a significant impact on sound quality, a comprehensive discussion of the many different transmission schemes available and their strengths and weaknesses is beyond the scope of this paper. We will discuss, however, particular audio equipment which may be required to compensate for the effects on sound quality of certain transmission media.

Part 2 - The Classroom

Room Acoustics vs. the Audio System

The sound that is sent out of the classroom to other sites begins with the classroom itself. The **acoustics** of the room - that is, the way in which the room affects sound waves - are determined by physical characteristics, such as the size of the room and what materials are used to construct and cover surfaces such as walls and floors. If the acoustics of the room are poor, the sound picked up by the audio system and transmitted to other sites will be unclear and fatiguing to listen to. In extreme cases, voices may be nearly unintelligible, or interaction may be so difficult that teaching cannot take place.

The classroom and the audio system both have a major impact on sound quality. For sound that is crystal-clear, and for the audio system to be as cosmetically appealing and "user-friendly" as possible, **both the acoustics of the classroom and the design of the audio system must be optimized**. In many instances, however, certain restrictions may force compromises in one area, which must be offset by optimization in the other area. For instance, if circumstances dictate the use of a classroom with poor acoustics, then there will be little room for compromise in the design of the audio system. Similarly, if budgetary constraints or user preferences force compromises in the design of the audio system, it becomes critical that the acoustics of the classroom be very good. When a poor audio system is combined with poor room acoustics, results are usually so unsatisfactory that instructors and students prefer not to use the system at all.

Click here for Room acoustics vs. audio systems figure

Room acoustics vs. audio system: if one must be compromised, the other must be optimized in order to maintain acceptable sound quality.

When you are present in the same room as a person talking, your brain makes use of both the aural information supplied by your ears and the visual information supplied by your eyes. This combination of sight, sound, and brain power allows you to "ignore" or "filter out" some of the noise and undesired sound, and to concentrate on the desired sound (the talker.) A microphone does not have this ability, so it must be able to "hear better" than a human listener would in order to pick up clear and intelligible speech. But what makes one room sound good, and another sound poor? And is it possible to know in advance whether a particular room is a good choice - from an acoustic standpoint - for distance learning?

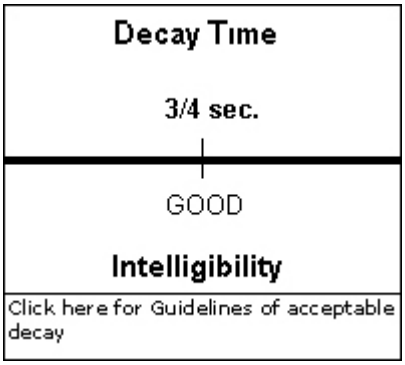
How to Tell if a Classroom is Acoustically Suitable for Distance Learning

Room acoustics is a broad term comprised of many components. For our purposes, there are two acoustic variables which have a major impact on the sound of a classroom: decay time and background noise level.

Decay Time

Sound waves emanate from a talker in all directions. Some travel directly from the talker to the microphone, while others take a roundabout route, bouncing off of the walls, ceiling, or floor. The reflected sound reaches the microphone later than the direct sound, and blends with it to become audible as a continuation or "smearing" of the original sound. Decay time is how long it takes for this reflected sound to weaken or "decay" to the point that it can no longer be heard. The decay time of a room is determined by its size, shape, and construction. The decay time in a large marble cathedral might be as much as 5 seconds; in a classroom with concrete block walls and tile floor it might be 1 or 2 seconds; in a conference room with thick carpeting and heavy drapes it might be 1/2 second.

If a room is too reflective, speech that is picked up by a microphone in that room will usually sound as if the talker is "at the bottom of a barrel" or "at the end of a long hallway." This is in spite of the fact that the sound may be perfectly acceptable to a live listener in the room. In general, the longer the decay time is, the worse the sound will be.



Click here for Guidelines of acceptable decay

Guidelines for acceptable decay time in a distance learning classroom.

Decay time is measured with special test equipment which generates a burst of "white" or "pink" noise, and then measures how long sound persists after the noise has ceased. The measurement is typically made by a professional sound system installer or acoustic consultant in the process of evaluating a classroom for distance learning use.

Background Noise Level

Simply put, "noise" is any sound that the listener does not want or need to hear. Low levels of background noise can sometimes be suppressed or "tuned out" by the brain for a few minutes, but this quickly causes listening fatigue. As the level of noise increases compared to the level of speech, intelligibility suffers and listeners begin to miss words. Typical sources of background noise that make listening more difficult in a classroom include:

- cooling fans in computers or overhead projectors
- air ducts that vibrate or rumble
- air vents that produce an audible "rush" as air moves through them
- people walking or talking in hallways outside the classroom
- equipment rooms located next to, above, or below the classroom
- fluorescent light fixtures that hum or buzz

A precise measurement of background noise in a room can be made using a device called an audio spectrum analyzer. The noise level is measured in units called decibels, abbreviated dB. Because sounds with different tonal characteristics affect the human ear differently, measurements are made at many points across the audible spectrum. The resulting data are then compared to standardized Noise Criteria or "NC" curves to determine the acceptability of the room for a given purpose. Rooms used for distance learning, teleconferencing, and similar activities should have an NC rating of 35 or less (which is very quiet.)

Another device, called a sound level meter or SPL meter, provides an average reading of the noise level in a room. Be aware, however, that the sound level meters sold at neighborhood electronics stores are usually not capable of detecting low frequency noise (such as the rumbling of an air duct) and therefore may not provide an accurate and useful measurement of the noise level in a classroom.

How Room Acoustics Can Be Improved

In most classrooms, some improvement to the acoustics of the room will need to be made. The most common need is for a reduction in the decay time of the room, which is usually accomplished by covering some of the surfaces (walls, floor, ceiling, and windows) with commercially-available materials or panels designed to absorb, rather than reflect, sound waves.

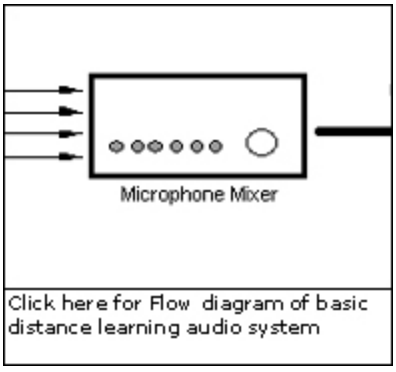
A reduction in background noise is typically addressed by repair or replacement of light fixtures, and adjustment of or modification to air conditioning vents and ducts. Noise coming from outside the classroom is usually more difficult to control, however. Footsteps in a hallway might be silenced simply through the addition of carpeting, while reduction of noise from highway traffic or nearby equipment rooms might require major reconstruction of walls, ceilings, or floors. Reducing the transmission of noise into the room from outside sources can be very expensive, and should not be attempted without the help of an experienced acoustic consultant. In some cases, it may be wise to consider an alternate location for the classroom.

Part 3 - The Audio System

Components of the Audio System

The particular equipment that makes up a distance learning audio system varies depending on class size, seating arrangement, the subject being taught, the available budget, and other factors. Certain fundamental pieces of audio equipment are common to nearly all systems, however:

- a wireless microphone for the instructor
- desk- or table-mounted microphones for the students
- a microphone mixer to control, balance, and combine the signals from the microphones
- an amplifier and one or more loudspeakers to distribute the audio from other classroom sites throughout the room



Flow diagram of a basic distance learning audio system.

Specific information about different types of microphones and wireless microphone systems, how they work, and how to choose the best type for a particular application is included in Guide to Better Audio, a complimentary booklet available from Shure Brothers Incorporated. Specific information about amplifiers and loudspeakers is available from manufacturers and vendors of those products.

Thanks to popular spy movies such as the James Bond series and "Sneakers," many people are under the impression that commonly available audio equipment can perform miracles, such as picking up intelligible speech from a mile away, or with a microphone hidden in an air duct. While it is probably true that a team of acoustic experts working for months with powerful computers could extract intelligible dialogue from a recording made that way, such feats are not possible during a live program or within the typical school system's budget. Modern audio systems can perform well under a wide range of conditions, but they cannot compensate for having poor sound fed into them. **Noise and reflected sound are impossible to remove once they are picked up and combined with speech.**

Fortunately, there are time-tested "rules" for designing audio systems that can minimize the effects of less-than-ideal acoustic conditions. Three of these are so important that, if they are ignored, there is almost no hope of achieving satisfactory sound quality no matter how much time, money, or effort is spent.

Three Things About the Audio System that "Make or Break" Sound Quality

1. Talker-to-microphone distance

One of the most significant factors in determining the performance of an audio system is the distance from the talker to the nearest microphone. As the microphone is positioned farther away from the talker, the loudness of the speech reaching the microphone decreases, so the microphone's sensitivity to sound - its ability to "hear" - must be increased to compensate. This causes the microphone to pick up more of the desired sound (speech), but also to pick up more of everything else - background noise, reflections, sound from the loudspeakers, etc. **The farther away the microphone is from the talker, the more hollow and noisy the sound will be.**

So, when it comes to microphone placement, how far is "too far"? It so happens that there is a certain distance from the microphone beyond which a talker will sound hollow and difficult to understand, regardless of what type of microphone is used or which way it is pointed. This is called the Critical Distance, abbreviated Dc. The Critical Distance is different for every room, and is determined primarily by the volume of the room (in cubic feet) and the decay time. **Those talkers who are at or beyond the Critical Distance from the nearest microphone will be difficult to understand, no matter what type of equipment is added to the audio system or how it is adjusted.** Given that most classrooms have a Critical Distance of from two to five feet, the following guidelines should be used for determining acceptable distance from the talker to the nearest microphone:

- less than 2 feet is ideal
- between 2 and 3 feet is good
- between 3 and 5 feet is marginal
- more than 5 feet is unacceptable

In a typical classroom, microphones should be located less than two feet from talkers.

When in doubt, always place the microphones nearer to rather than farther from talkers. **Moving microphones closer to talkers is the single most significant improvement that can be made to most classroom audio systems.**

The Best Places To Locate Microphones In a Classroom

We've discussed just how important it is to place microphones close to talkers, but where exactly should microphones be located to pick up students' questions? The answers depend on how the classroom is used and on the seating arrangement. What subjects are taught in the classroom? If the schedule includes foreign language classes, or advanced courses that include lots of technical terms, intelligibility is critical. In this case, microphones should probably be placed on the student desks so that they are less than two feet from the talkers. Lecture-type classes that do not rely on heavy student interaction may permit slightly longer talker-to-microphone distances.

If it is likely that students will be spreading out books and papers on the desks, flat surface microphones may be inadvertently covered up, resulting in muffled sound or pickup of rustling noises. Slim, flexible "gooseneck" microphones solve this problem by elevating the sensitive part of the microphone above the surface of the desk - away from the noise and closer to the talker.

The toughest situation is when the room layout must be changed regularly. If microphones cannot be mounted on student desks or tables, the only remaining option is usually to suspend microphones from the ceiling. The longer talker-to-mic distances required for adequate head clearance when students are entering and leaving the classroom represent a significant compromise in the audio system design - one that usually cannot be completely compensated for. **Excellent room acoustics are absolutely essential in classrooms which utilize suspended microphones. If room acoustics are poor or merely average, then suspended microphones should never be considered.**

The Case Against Ceiling Microphones

For appearance and security reasons, it is always tempting to place microphones directly on the ceiling of the classroom, where they are out of sight and out of reach. This is absolutely the worst location for microphones, however, and virtually guarantees that sound quality will be terrible in all but the quietest and most acoustically-perfect rooms.

First of all, ceiling microphones are far beyond the Critical Distance for most rooms, making voices sound hollow and distant. Second, ceilings almost always contain air vents which produce noise, and air ducts which cause the ceiling to rumble and vibrate. Ceiling microphones are closer to these undesired sounds than they are to the students - exactly the opposite of the way things should be for intelligible voice pickup. Finally, students do not talk up toward the ceiling; if anything, they talk down at the desk or the floor!

2. Number of open microphones

An often-overlooked factor in audio system performance is the number of open microphones, abbreviated NOM. This is the number of microphones which are "live" or "open" at any moment, meaning that the sound that they pick up is being recorded on tape or heard by other sites on the network. Only those microphones which are "open" affect sound quality; mics that are turned off by a switch or turned down all the way by a volume control do not.

While you might expect that using several microphones to pick up the sound of a talker would sound better or louder than a single microphone, in reality it sounds much worse. This is because each additional microphone picks up some of the background noise and reflected sound in the room, even though it is not picking up the words of the talker.

Having four microphones turned up when only one person is speaking results in audio that is nearly 90% noise and reflected sound being transmitted to other sites.

So, if only one person is speaking and four microphones are open, the audio system is fed four times as much background noise and reflected sound as with just one open microphone, but no additional speech (because the additional three microphones are probably too far away to clearly pick up the talker.) What this means is that only the microphone nearest to the talker should be turned up. If you want to hear what a difference this can make, make a tape recording of one person talking in a room, first with several open microphones and then with only one open microphone. The improvement in sound quality that results from turning off the unneeded microphones is dramatic.

What can you do to keep unneeded microphones turned off in the classroom? There are really only three options: have a designated operator turn the microphones on and off as needed; have the students operate their own microphones; or have an automatic microphone mixer do it.

If a trained person is available to operate the sound system during every class, that person could be responsible for turning the appropriate microphones on and off when students speak. This is usually a poor choice, however, because even the best operator cannot react to a talker until a few words have already been missed - and a student's question may only consist of a few words. Another option is to require the students to control their own microphones. This is done using Push-to-Talk or "PTT" microphones, which require the student to push and hold a button to be heard. This can be effective *if the students remember to push the button when they want to talk*. Depending on the age and interest level of the students, this may or may not be a reasonable expectation. Some instructors feel that forcing students to make such an effort before they can speak creates a barrier to interactivity, while others (especially those who teach several remote sites at once) appreciate the "shield" from unwanted distractions and interruptions which manually-operated microphones can provide for the instructor. An additional concern is that the students who are in the same room as the instructor usually do not feel compelled to activate their microphones when they talk, with the result that students at other sites cannot hear them.

A third solution to the problem of keeping unneeded microphones turned off is to use an automatic or "voice-activated" microphone mixer. This is a microphone mixer which automatically turns individual microphones on and off in response to the presence of sound at the microphone. Basic automatic mixers use a simple "fixed threshold" method to decide when to activate microphones. With this method, the sound level at any microphone must exceed a preset minimum (called the "threshold") before the microphone will be turned on and the talker will be heard.

Proper adjustment of fixed threshold models is critical, because background noise levels within the classroom usually change from day to evening or even from hour to hour, and speaking levels vary significantly between individuals. For instance, if the threshold is set low enough so that a quiet talker can activate the microphone, then the system may be overly sensitive to background noise, and microphones may activate every time the air conditioning turns on, or when the hallway fills with students during a passing period. Conversely, if the threshold is set high enough to prevent such incidences of false activation, then quiet talkers may not be heard.

More sophisticated automatic mixers are available which constantly adapt to changes in background noise level. These units feature a "floating threshold" which is referenced to the level of noise in the room. Talkers need only speak slightly louder than the background noise level to activate a microphone. These systems are generally easy to set up and require almost no fine-tuning, since they adjust themselves to changing conditions in the room.

3. Microphone pickup pattern

It is beyond the scope of this document to review all of the different types of microphones available. In general, however, directional microphones should always be used in distance learning classrooms. Directional microphones (also called unidirectional) favor sounds from the direction in which the microphone is aimed, and reject sounds coming from behind the microphone. This trait offers two very important benefits which make directional microphones especially suitable for use in distance learning classrooms. First, they can be aimed toward a desired sound source (the students), and away from an undesired sound source (the loudspeakers.) This helps to prevent the sound from other sites (coming out of the loudspeakers) from being picked up by the microphones. This loudspeaker audio would otherwise be retransmitted, which could cause annoying echoes or howling. Second, most directional microphones pick up only one-third as much background sound as non-directional types, making them far less sensitive to the ambient noise and reflected sound present in the room. With less noise and reflected sound mixed in with the audio, speech is clearer and more intelligible.

Note that a directional microphone begins to lose its effectiveness as the distance from the talker increases. The further it is from the talker, the less improvement in sound quality it can offer over a non-directional model. In fact, when placed near (or beyond) the room's Critical Distance, a directional microphone will sound just as poor as a non-directional type.

Common Problems with Distance Learning Audio Systems and What You Can Do About Them

A live, two-way interactive communications link is more complicated than a regular audio system used for public address or recording. The three major audio problems which plague distance learning classrooms are feedback, transmission echo, and reflected or "hollow" sound. While feedback and reflected sound are commonly encountered in many sound reinforcement systems, echo is unique to two-way communications.

Feedback

Feedback is the howling or squealing that is heard when sound from a loudspeaker is picked up by a microphone and reamplified. **Feedback can easily occur between audio systems located in different rooms**, if the microphones in each room pick up too much of the sound from the nearby loudspeakers and retransmit it to other sites, where it can be picked up by microphones and transmitted back again.

Leakage from loudspeakers into microphones, causing feedback or echo.

There are many factors which can contribute to microphone-to-loudspeaker leakage, so there are many possible solutions which may work in a given classroom. Here are the corrective measures which are most successful at eliminating feedback in a distance learning network:

- Change the positioning and/or proximity of the microphones and loudspeakers relative to each other. For best results, loudspeakers should be positioned behind (not above) typical directional microphones, which are less sensitive to sounds arriving from the rear than to those arriving from the front.
- Turn the loudspeaker volume down in the room. Lower volume levels, while making it more difficult for people to hear, reduce the tendency of the audio system to howl.
- Reduce the number of open microphones (NOM), through the action of a live operator, or the use of Push-to-Talk microphones, or an automatic mixer. Reducing the number of open microphones has the same effect as turning down the overall volume of the audio system (but without the penalty of lower listening levels), thereby reducing the incidence of feedback.
- Make the surfaces in the room less reflective by adding sound absorbent panels or coverings. In rooms with less-than-optimal acoustics, microphone-to-loudspeaker coupling may occur even though there is no direct path between the two. In this case, sound leaves the loudspeaker and is reflected off of the walls, ceiling, or floor, reaching the microphones indirectly.

Transmission Echo

Some types of transmission networks slightly delay the audio and video signals before or during transmission. This may be due to the time required for satellite transmission or the action of a device called a codec, which compresses the signal so that it can fit into a smaller (and less expensive) amount of space on the transmission line. When distance learning sites are connected over a network which induces some signal delay, the sound from the loudspeakers at the remote site can leak into microphones there, which causes an echo to be returned to the originating site. In other words, a talker in Classroom A speaks, his or her voice comes out of a loudspeaker in Classroom B and leaks into a microphone there, and that signal is transmitted back to Classroom A, where the talker hears an echo of his or her own words 1/4 to 1 second after having said them. If the leakage problem in Classroom B is not severe, the returned echo may be low enough in volume to be tolerable, but in almost all cases it is so annoying that conversation is impossible.

Various methods of dealing with echo have been devised; most of these were intended to minimize echo in long distance telephone lines. One type of device, called an echo canceller, monitors the incoming (or 'Receive') audio from other sites, and compares it to the signal that is about to be transmitted (the `Send' signal). If the echo canceller detects the presence of the incoming audio in the outgoing signal, it creates a replica of the incoming audio and electronically subtracts it from the outgoing signal. This reduces the amount of echo, but does not completely "cancel" it. Notice that the echo canceller attempts to prevent the incoming audio from other sites from being sent back to them, but it does not do anything about the echoes that other sites may be sending to your site. For this reason, if one site on a network requires echo cancellation equipment, all of the sites on that network will almost certainly need it.

There are two general types of echo cancellers. The first, called a line echo canceller, is designed to remove electronic echoes from telephone lines; most long distance telephone circuits employ these devices. Line echo cancellers cannot significantly reduce the complex echoes which result from loudspeaker-to-microphone leakage in a classroom. The second type, called an acoustic echo canceller, is designed to reduce the chance of an echo being produced due to this leakage. **Acoustic echo cancellers are commonly mistaken to be capable of removing the hollow sound associated with a room that is too reflective; no electronic device can do that.** In fact, excess reflected sound makes it more difficult for the echo canceller to work properly, and reduces the degree to which it can reduce transmission echo.

Acoustic echo cancellers take time (1/10 of a second or more) to "learn" how to reduce echo in a particular room, and they have to go through this learning process whenever the path from loudspeaker to microphone changes. This might be caused by a wireless microphone user moving around the room, or microphones being turned on and off by an automatic mixer. During these "learning" periods, echoes will not be reduced.

Echo cancellers are expensive, and are not an alternative to good room acoustics and proper audio system design. At best, they can improve the sound quality of a distance learning network that suffers from echo problems, but they cannot make a classroom that has poor acoustics sound good.

Reflected or "Hollow" Sound

One of the most persistent and annoying problems with distance learning audio systems is the hollow sound - as if the talker is "at the bottom of a barrel" - caused by a room that is too reflective. Unfortunately, reflected sound cannot be removed by any type of electronic device; it must be kept out of the microphones in the first place.

The obvious solution, of course, is to make the room less reflective by covering surfaces with specially designed sound-absorptive materials. If changes to the room acoustics do not provide a sufficient improvement, the number of simultaneous open microphones (each of which adds a measure of reflected sound and background noise to the audio signal) must be reduced. Directional microphones can also reduce pickup of reflected sound, but only if they are positioned at less than the Critical Distance from the talker. Beyond the Critical Distance for the room, directional microphones offer minimal benefit. Finally, microphones can simply be moved closer to the talkers. Because the speech reaching the microphones will then be louder, the sensitivity of the microphone can be turned down at the microphone mixer, thereby decreasing its sensitivity to reflected sound and background noise as well.

THE BROADCASTER'S SECRETS

Television news shows routinely feature live interviews by satellite with leaders around the world. Somehow, they never seem to experience any of the audio problems that plague many distance learning networks. What do broadcast engineers do that allows them to dodge the effects of feedback, echo, and reverberation? Here are three "audio commandments" that broadcasters live by:

1. **Place the microphones as close to the talker as practical.** In the studio, news anchors always wear a very small microphone (called a "lavalier" type) clipped to the necktie or jacket. In the field, reporters may wear a lavalier or use a standard handheld microphone. Because the camera shot is usually a tight close-up the microphone may not be visible, but rest assured that it's no more than a foot or so away from the talker's mouth. In situations where the talker cannot wear or hold a microphone, a long "shotgun" type microphone is mounted on a pole and held by a technician above and in front of the talker, just outside of the camera's field of view. While effective for recording, shotgun microphones offer little advantage when used in a classroom. They, too, sound poor when used indoors at or beyond the Critical Distance of the room.
2. **Use an ear piece.** Broadcasters hear each other, the guests, the director, the commercials, and everything else through a small flesh-colored earphone worn in one ear. In high-noise environments such as sports events, the commentator wears a tight-fitting headset (to block out noise) with a boom microphone positioned just an inch or so from the mouth (for clear speech with minimal noise pickup.) Loudspeakers are rarely used, so loudspeaker-to-microphone leakage is eliminated. No leakage means no problems with feedback or echo. This is especially critical, given that remote interviews by satellite - which are subject to significant signal delays - often must be set up on a moment's notice.
3. **Use as few open microphones as possible.** Fewer microphones pick up less noise, and require less time to set up and plug in. To optimize sound quality, an engineer constantly adjusts or "rides" the settings at the microphone mixer. You will rarely see more than four microphones being used at one time on television, but when more microphones are required than the engineer can keep up with, automatic mixers are frequently used.

Who Can Install the Audio System in Your Classroom

Hopefully, you are beginning to have a better understanding of the technical issues which must be dealt with in the design, installation, and use of a distance learning audio system. These may require more time or technical expertise than you can commit to the project. In any case, one of the following three options should help you to get a distance learning classroom installed at your institution:

1. **Work with a qualified A/V consultant or sound system contractor.** An acoustic or A/V consultant designs systems and writes what is known as a spec, or specification, of the equipment and room modifications required for the project. The consultant does not actually sell or install the equipment, however. A sound system contractor, working from the consultant's design, sells, installs, and services the equipment. In some cases, the contractor both designs and installs the system. It is very important to work with firms that have experience with two-way interactive systems, such as teleconferencing or videoconferencing rooms or distance learning classrooms, because of the unique problems which arise in them as opposed to more typical public address systems found in churches or auditoria.
2. **Purchase a pre-packaged system from a turnkey system provider.** Companies which offer certain key elements of a distance learning system, such as fiber optic transmission equipment or service, sometimes "bundle" their own products or services together with those of companies that make the other equipment necessary (such as cameras, monitors, etc.) They are then able to market a complete distance learning system package for one price. In most cases, the actual installation of hardware is handled by a local sound system contractor.
3. **Do it yourself.** Institutions that have qualified technical people on staff with a knowledge of audio, video, and room acoustics, may be able to configure, install, and service a distance learning system without assistance. This may be a viable option if the system is a simple one - meaning that class sizes are small, echo is not a problem, and necessary modifications to the room acoustics are minimal.

For Those Who Want to Learn More:

Additional sources of information:

Guide to Better Audio
by Christopher Lyons
(27 pages; complimentary) available from Shure Incorporated, Niles, IL
Basic primer on microphones, wireless microphone systems, and manual and automatic mixers. For those with little or no audio background or technical training.

Architectural Acoustics
by M. David Egan
(411 pages, hardcover; approximately $65.00) available from McGraw-Hill, Inc.
Complete review of audio theory, sound absorption and isolation, room acoustics, noise and vibration control, electronic sound systems, and more. Many useful examples, illustrations, tables, and equations.

Teleconferencing and Distance Learning
by Patrick Portway and Carla Lane
(384 pages, softcover; approximately $50.00) available from Applied Business teleCommunications, San Ramon, CA 510-820-5563 tel/510-820-5894 fax
Collection of papers written by representatives from equipment manufacturers and industry associations. Chapters cover audio, echo cancellation, instructional design, transmission standards, training instructors, and more.

Audio Systems Design and Installation
by Phillip Giddings
(574 pages, hardcover; approximately $60.00)
Comprehensive reference guide to audio system powering, grounding, wiring, and installation. Extensive discussion of equipment interconnection and noise problems.