REFERENCE	DESIGN	RECRUIT-MENT	CASE DEFINITION	SUBJECTS	ASSESSMENT TOOLS	RESULTS	AUTHOR'S CONCLUSIONS
Anderson KL, Goldstein H. Speech perception benefits of FM and infrared devices to children with hearing aids in a typical classroom. Lang Speech Hear Serv Sch. 2004;35(2):169–84.	Single-subject alternating treatments design to compare the speech perception of hard-of-hearing students using HA* with each of 3 FM* or IR* devices.	Large school district; all educated in inclusive general education classrooms without sign language.	Criteria for inclusion: (1) Congenital mild–severe hearing loss that was normal in low frequencies but at least mild–severe above 1 kHz.* (2) Audiogram obtained no more than 1 year before testing. (3) Aided speech recognition under sound field condition within normal–mild hearing loss range.	Children with mild–severe hearing loss: N = 8 Controls: N/A Eight long-time HA users with various degrees of hearing loss (mild–severe). Aged: 9–12 years who were primarily auditory communicators and learners. Aided thresholds in the normal–mild hearing loss range.	Average-sized kindergarten classroom with 10+ dB* SNR* and RT* of 1.1 seconds used. Children seated 3 meters away (outside of the critical distance) performed HINT* at 10 dB SNR (pre-FM or IR amplification), with cafeteria noise at 60 dB. Children performed task using (1) HA alone; (2) HA with ear-level FM, personal-desk FM; and (3) IR classroom amplification system.	No benefit of IR system with HA over HA alone. Clear benefit of using ear-level FM and desktop FM over HA alone. Desktop and ear level FM systems showed relatively equal benefit. Most children subjectively preferred ear-level FM over other systems.	Benefits of classroom amplification was not as strong as predicted. Lack of clear benefit might have been the result of relatively high RT (1.1 seconds) of classroom. Benefit might be higher in a classroom with ANSI* recommendations of 0.4–0.6 seconds. Classroom amplification might be the easiest to incorporate into mainstream schools. Desktop or ear level FM systems are recommended for children with hearing loss, especially in reverberant environments. Degree of hearing loss not a predictor of amount of benefit obtained from IR or FM system use over HA alone. Six of 150 HINT sentences proved especially troublesome for most of the children with hearing loss. Might be due to gaps in vocabulary.

* HA = hearing aid; FM = frequency modulated; IR = infrared; kHz = kilohertz; dB = decibel; SNR = signal-to-noise ratio; RT = reverberation time; HINT = Hearing In Noise Test; ANSI = American National Standards Institute

REFERENCE	DESIGN	RECRUIT-MENT	CASE DEFINITION	SUBJECTS	ASSESSMENT TOOLS	RESULTS	AUTHOR'S CONCLUSIONS
Hawkins DB. Comparisons of speech recognition in noise by mildly-to-moderately hearing-impaired children using hearing aids and FM systems. J Speech Hear Disord. 1984;49(4): 409–18.	Case Study *Purpose*: To compare speech recognition in noise for children with mild-to-moderate hearing losses using a variety of hearing aid and FM* system-HA* combinations in a school classroom.	Not specified	Pure tone thresholds for: .25, .5, 1, 2, 4 kHz* Thresholds for each frequency reported at least 15 dB* at one frequency and up to a maximum of 90 dB at one frequency.	Nine children with mild–moderate bilateral SNHL.* Controls: N/A Age: 8 years, 4 months–14 years, 7 months. All attended regular classrooms. 7 out of 9 wore FM systems at school.	All testing done in 7 x 9 x 2.6 meter classroom; reverberation measured. (17 conditions total). 11 test conditions in which adaptive procedure employed. 6 conditions in which word recognition test employed.	If HA alone is used, better speech recognition in noise might occur if the aid has a directional microphone. The advantage of FM over HA alone can be substantial. When the environmental microphone is activated, the SNR* advantage of an FM system is reduced substantially.	Seven recommendations made regarding amplification: (1) If HA alone used in classroom, better speech recognition in noise might occur if directional microphone used. (2) Advantage of FM versus HA alone can be substantial. (3) When environmental microphone is activated, SNR advantage is reduced substantially. (4) A directional teacher's microphone should be used. (5) Although no differences were found among 3 methods of coupling FM receiver to personal HA, direct input would seem to be the method of choice because it avoids the problems inherent in inductive coupling. (6) The magnitude of the FM advantage over personal HA alone decreased as classroom SNR improved. However, an FM advantage was still seen in a quiet classroom. (7) An optimum classroom amplification system using personal FM would consist of (a) directional teacher's microphone; (b) FM receiver coupled via direct input to binaural HA with directional microphones; (c) switch positions on HA allowing for choice of HA only, FM only, or FM + HA mice.

* FM = frequency modulated; HA = hearing aid; kHz = kilohertz; dB = decibel; SNHL = sensorineural hearing loss; SNR = signal-to-noise ratio

REFERENCE	DESIGN	RECRUIT-MENT	CASE DEFINITION	SUBJECTS	ASSESSMENT TOOLS	RESULTS	AUTHOR'S CONCLUSIONS
Tharpe A, Ricketts T, Sladen D. FM systems for children with minimal to mild hearing loss. ACCESS: Achieving Clear Communication Employing Sound Solutions. Proceedings of Chicago conference, Nov. 2003;191–9.	Repeated measures ANOVA.* Subjects fitted with an ear level FM* receiver with no volume control: (1) monaural with open mold, (2) monaural with skeleton mold, (3) bilateral with open mode. Transmitting microphone set to directional mode. Subjects tested in FM condition plush unaided condition.	Not specified.	All had permanent hearing loss. PTA* of poorer ear across subjects = 34 dB* HL.* (1) Minimal–mild bilateral: PTA >25 dB but <45 dB HL bilaterally (57%, N = 8). (2) High frequency: thresholds of ≥25dB HL at 2 or more frequencies above 1 kHz* bilaterally (21%, N = 3). (3) UHL:* ≥45 dB PTA (21%, N = 3).	Total: N = 14 (10 boys, 4 girls) With bilateral hearing loss: N = 8 With UHL: N = 3 With high frequency: N = 3 Controls: N/A Mean age 8.0 years (5.0–11.0 years). Normal cognitive function (determined by school placement and parental report); 21% repeated a grade; 14% had or were receiving resource assistance.	*Speech Perception:* HINT-C* presented via loudspeaker under 4 listening conditions in background noise. Participants repeated sentences. *Teacher Questionnaire:* SIFTER* administered prior to and following each 2-week trial period with an FM configuration (total of 4 administrations). *Self-Report:* 8-item self-report tool developed for this study.	*Speech Perception:* Performance in unaided condition poorer than all FM conditions. Significant effect of ear mold type. No significant effect of FM configuration. Open earmold condition superior to monaural open earmold condition. *Teacher Questionnaire:* Teachers unable to identify differences between 3 FM configurations, thus only results from baseline versus last SIFTER administration reported. No overall significant difference between baseline and last SIFTER, but teachers ranked children as having improved academics. *Self-Report:* Participants unable to make reliable distinctions among 3 FM configurations, thus only results from last self-report provided. Overwhelming majority liked ear level FM devices and purchased system.	Children with minimal hearing loss showed better speech perception in noise when wearing FM systems compared with unaided conditions. Bilateral FM placement resulted in better speech perception scores than monaural placement only when sound source located at 0º or 270º azimuths. SIFTER findings consistent with similar studies. Results of self-report showed children accepted and benefited from FM systems.

* ANOVA = analysis of variance; FM = frequency modulated; PTA = pure tone average; dB = decibel; HL = hearing level; kHz = kilohertz; UHL = unilateral hearing loss; HINT-C = Hearing in Noise Test for Children; SIFTER = Screening Instrument for Targeting Educational Risk

REFERENCE (Review)	OBJECTIVE	ARTICLES REVIEWED	RESULTS	AUTHOR'S CONCLUSIONS
Bess F. Classroom acoustics: an overview. Volta Review. 2000;101(5): 1–14.	Highlights the importance of classroom acoustics on ability of children with hearing loss to learn. Examines some of the seminal research on classroom acoustics and suggest implications for education.	These studies involved the comparison of children with no hearing loss to those with hearing loss and the acoustics of different classrooms. The following articles were reviewed: Sanders (1965) study on classroom acoustics (used 47 classrooms from 15 schools). Finitzo-Hieber and Tilman (1978) study that investigated speech recognition performance under noise conditions in a group of children with no hearing loss and a group with either mild or moderate hearing loss. Bess, Dodd, and Parker (1998) study involved young school-aged children. Showed those with minimal hearing loss reported less energy than those children with normal hearing.	Reports demonstrate that modern classrooms occupied by children with hearing loss exhibit noise levels that far exceed the basic recommendations. Noise can also result in harmful effects among children with minimal sensorineural and UHL*, learning difficulties, auditory processing problems, and middle ear disease with effusion. Children with hearing loss experience far greater difficulty for the same RT* than their peers with no hearing loss. Combined effects of noise and reverberation serve as competing background for children with hearing loss. Children with hearing loss experience difficulties in understanding speech and expend a lot of energy to listen to spoken messages when there are adverse conditions (e.g., noise). Children with minimal hearing loss reported less energy or were tired more frequently than those children with no hearing loss.	Efforts to provide appropriate remediation for children with hearing loss will be futile if classroom acoustics are not improved. The acoustics of many educational settings (e.g., classrooms) affect the ability of children with hearing loss to learn. The development of guidelines related to the acoustics of educational settings could serve as a first step in helping children with hearing loss succeed in school. Ensuring favorable SNR* in relation to a child's ear and the speaker is needed.

* UHL = unilateral hearing loss; RT = reverberation time; SNR = signal-to-noise ratio; dB = decibel

REFERENCE (Review)	OBJECTIVE	ARTICLES REVIEWED	RESULTS	AUTHOR'S CONCLUSIONS
Crandell CC, Smaldino JJ Classroom acoustics for children with normal hearing and with hearing impairment. Lang Speech Hear Serv Sch. 2000;31:362–70.	To review the effect of poor listening environments on different populations, including children and adults with sensorineural hearing loss.	Reviewed several articles about speech perception in noise, classroom noise levels, reverberation time, effects of reverberation time, and noise on children and adults with sensorineural hearing loss.	The ability of noise to mask the signal (i.e., target sounds, such as speech) depends on acoustic parameters such as intensity of noise, fluctuation of the intensity of noise, and long-term frequency spectrum of noise. Noise generated by the class, such as talking, masks speech the most. Low-frequency noise such as heating, venting, or air conditioning systems has a great impact due to upward spread of masking. Teachers in classes with greater background noise (e.g., classes with a lot of traffic or aircraft noise) exhibit greater tension, fatigue, and discomfort. RT* is the time required for a sound to decrease in amplitude by 60 dB* and is measured at 0.5, 1, and 2 kHz.* High RT causes prolongation of spectral energy of vowels and filling of temporal gaps. The critical distance is defined as the distance in which the noise equals the signal. In an average sized classroom, critical distance equals approximately 3–4 meters. Adult listeners with no hearing loss require a SNR* of 0, listeners with sensorineural hearing loss require 4–12 dB better, and an additional 3–6 dB in rooms with moderate RT. Adult listeners with normal hearing require RTs of 1 second or less; those with sensorineural hearing loss require <0.4 second. Children with mild hearing loss performed poorer than those with no hearing loss in most listening conditions. The discrepancy increased with the complication or difficulty of the listening task.	The study proposes using a noise criteria curve to describe background noise. Preferential seating in the classroom for at-risk children should be within the critical distance. Results indicate children in typical classrooms have greater difficulty understanding speech than has traditionally been suspected. The authors recommend SNR >15 dB and an RT <0.6 for classrooms of adult listeners with sensorineural hearing loss.

* RT = reverberation time; dB = decibel; kHz = kilohertz; SNR = signal-to-noise ratio

REFERENCE (Review)	OBJECTIVE	ARTICLES REVEIWED	RESULTS	AUTHOR'S CONCLUSIONS
Davis J. Utilization of audition in the education of the hearing-impaired child. In: F Bess, B Freeman, J Sinclair (eds.), Amplification in education. Alex Graham Bell Assn for Deaf: Washington, DC. 1981;109-20.	To summarize data on what professionals believe about audition (e.g., use of residual hearing) and what is actually done to ensure its best use. To report on available data related to the role of residual hearing and outcomes of children with hearing loss.	Briefly discusses several studies about data related to the usefulness of audition.	Discusses the available data related to the use of audition as well as highlighting its limitations and the need for additional information. Most research up until the publication of this chapter in 1981 did not address the use of auditory input by children with mild or moderate hearing loss. Children with relatively good speech perception under quiet conditions can show reduced speech discrimination when exposed to the noise and reverberation conditions that exist in the average classroom.	Audiologists should use amplification in educational settings for all children with hearing loss. This will require recognition of the effects of mild–moderate hearing loss. It is important to collect data on the use of hearing in educational endeavors, the effects of different types of amplification on speech reception in educational settings, as well as the effects of various interventions (e.g., auditory training and academic tutoring), and other related areas. Efforts should focus on how to best integrate residual hearing of individual children with other approaches (e.g., visual).

REFERENCE (Review)	OBJECTIVE	ARTICLES REVIEWED	RESULTS	AUTHOR'S CONCLUSIONS
Flexer C. Audiological rehabilitation in the schools. ASHA. 1990;32(4):44–5.	To highlight factors that need to be considered in order to create a foundation for the delivery of audiological rehabilitation services. To discuss two general categories of audiological rehabilitation: (1) Appropriate use of technology to enhance SNR* in an educational setting and (2) advocating for teaching children to use hearing.	Reviewed several articles about speech perception in noise, classroom noise levels, RT,* and effects of RT and noise on children and subjects with sensorineural hearing loss.	*Laws:* Code of Federal Regulations on Education Title 34 states that audiological services should be provided to children who are deaf or hard-of-hearing. "Hard-of-hearing" (in children) is defined as permanent or fluctuating hearing loss that impairs education. A system set up for deaf children must accommodate a greater percentage of hard-of-hearing children. In 1986, less than 1% of 8 million children with hearing loss had access to audiological services that could improve their educational performance. Title 34 states that hard-of-hearing children are entitled to language habilitation and auditory training. Federal law supports the provision of audiological services with all degrees of hearing loss. *Schools:* Audiologists need the help of school officials and should not assume schools are informed about hearing loss. Many school-support services based on the "failure model" (i.e., services are not provided until the child begins to fail). The IEP* is important in the implementation of auditory support services and an audiologist should be part of the IEP team. Typical classroom does not have appropriate SNR for hard of hearing children. Technology such as FM*/direct-audio-input systems improve SNRs in classroom. FM and auditory training should combine to teach child what to listen for.	The audiologist is the professional best able to manage the complete hearing care of a child with hearing loss of any degree. Audiological habilitation begins with an understanding of the realities of working in an educational setting, including legal requirements, the necessity of administrative support, the "failure model" of service delivery, and the importance of the IEP. FM equipment needs to be fitted carefully and used and maintained judiciously.

* SNR = signal-to-noise ratio; RT = reverberation time; IEP = Individualized Education Plan; FM = frequency modulated

REFERENCE (Review)	OBJECTIVE	TOPICS DISCUSSED	RESULTS	AUTHOR'S CONCLUSIONS
Smaldino JJ, Crandell CC. Classroom amplification technology: theory and Practice. Lang Speech Hear Serv Sch. 2000;31:371–5.	To present data about the listening environments in school classrooms, challenges to improving them. To explain why poor listening conditions are detrimental to learning in all children including those with hearing loss.	Sources of classroom noise and their detriment to speech communication as a function of frequency are discussed. Assistive auditory technology is addressed, including FM* and HA.*	Appropriate SNR* for children with no hearing loss is +10 to +15 dB.* Children with hearing loss often require >15 dB SNR. Poor classroom acoustics adversely affect lecturing and cooperative learning activities. Acceptable range of reverberation time is 0.4–0.6 seconds. Most heating, venting, and air conditioning systems in classrooms are inexpensive models that are very noisy. Most classrooms cannot be retrofitted to reduce noise and most schools cannot afford the more expensive, quieter systems in new classrooms. Hearing aids with FM systems, noise canceling algorithms, and directional microphones can provide an advantage in some environments. If noise is diffuse, directional microphones provide no or minimal benefit. Directional microphones are not appropriate for many cooperative exercises. Noise-canceling hearing aids are often ineffective in classes with large reverberation times. FM systems provide benefit only if the speaker speaks into the microphone.	Even improving classroom acoustics migh not be sufficient for at-risk populations such as children with hearing loss, English as a second language, central auditory processing disorders, language learning impairments, etc. Poor listening environments can result in a "snowball effect" in which the child grows progressively more inattentive, and looses the central auditory ability to detect an auditory signal. Amplification technology can supplement good classroom design by improving listening condition for the many children who need favorable acoustics for auditory learning. Children must learn to use amplified signals, and teachers must learn to adapt amplification technology to their particular classroom teaching styles.

* FM = frequency modulated; HA = hearing aid; SNR = signal-to-noise ratio; dB = decibel