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Making Sounds Louder and Speech Clearer Through Educational Amplification for Children who are Hearing Impaired in Developing Countries: A Systematic Literature Review

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Abstract

Educational amplification is an assistive system used in classrooms to educate children with hearing impairment. Unsatisfactory acoustic qualities of classrooms lead to diminished speech intelligibility and distorted sounds, resulting in unfavorable learning and developmental concerns, particularly in children who are hearing-impaired. This paper aims to find out: (1) what the acoustic features are like in classrooms in which hearing impaired children are taught in developing countries; (2) the types of classroom amplification technologies implemented in order to assist hearing-impaired children; (3) what the current needs are for educational amplification in the classrooms of developing countries; (4) whether or not protocols are established for ensuring that children with hearing loss have access to a suitable hearing environment for learning and development in these countries. A systematic literature review was employed to conduct this study. Results obtained revealed that based on National Standards and research, the range for the background noise levels and reverberation time in unoccupied classrooms for children with hearing impairments or language delays were <20-35dBA and <0.3-0.7s respectively. Established protocols were evidently lacking in terms of ensuring that children with hearing loss have access to suitable, acoustical learning environments. Additionally, noise had a significant impact on the listening environment in classrooms, and thus limited the learning experience. However, amplification systems currently being used in classrooms have positive impacts, benefitting all listeners. It was concluded that there is a need for educational amplification in classrooms of developing countries nevertheless, more research is required on this phenomenon.

Keywords: Classroom acoustics; Educational amplification; Hearing impaired; Listening systems; Phonological attributes

Abbreviations: RT: Reverberation Time; WHO: World Health Organization; SNR: The Signal-To-Noise Ratio; MARRS: Mainstream Amplification Resource Room Study; FM: Frequency Modulated; AFILs: Audio-frequency Induction Loops; dB: Decibel; STI: Speech Transmission Index; SD: Standard Deviation

Introduction

Making Sounds Louder and Speech Clearer Through Educational Amplification for Children who are Hearing Impaired in Developing Countries: a systematic literature review. Classrooms are learning spaces where transmission of information from the teacher occurs across hearing and verbal platforms (Flexer, 1993 as cited in Palmer, 1997). Students are expected to be able to concentrate on listening to what is being said by their teachers. The acquisition of knowledge most times happens via auditory and verbal modalities [1]. Berg, 1987 as cited in Palmer 1997 reports that children are focused on hearing engagements up to 45% of the day while in school. An average of 45-75% of the time spent by children in a classroom setting is used to actively pay attention to what is being said by teachers and peers [2].

Rationale for the Review

Modern day technology such as multimedia systems used as a teaching modality also involves the need for children to listen. Current teaching techniques involves the students as well in group activities in addition to audio, visual and computer systems as significant ways of gathering knowledge [3]. For most of the daylight hours, children are in classrooms paying attention to information being taught, socialising with classmates, and getting to understand their teacher [4]. According to [1], it would be fair to surmise that for a child to attain scholastic achievements he/she most definitely should possess the ability to process and understand audible signals. Disruption in this transfer of audio-verbal information within the classroom setting will undoubtedly have a detrimental effect on the overall learning experience of students. The auditory capacity of children continues to develop as they age and as such, they are unable to process sounds in the same way adults do. Their processing of aural data is affected by sensorial, attentional, and cognitive parameters.

An unfavorable acoustic environment has the potential to negatively affect speech and phonetic understanding as well as create issues with auditory processing and cognition [4]. Noisy classroom environments for children who are in the developmental phases of phonological attributes will have a hard time comprehending distorted verbal expressions and maintaining activities involving cognitive functions [4]. For children with hearing impairment, background noise aided by other barriers to listening and communication leads to a slower pace at which they learn and develop. Youngsters with loss of hearing encounter more difficulties than their hearing counterparts in comprehension of speech in unsuited listening spaces [5]. Saravanan et al. [6] explains that an ideal hearing environment within the classroom is essential for children who suffer from hearing disability for them to obtain positive educational outcomes. Despite this notion of making learning areas better, children, particularly those in developing countries who suffer from hearing impairment are still within schools where the listening conditions are doubtful [6].

Regarding barriers to communication, it is imperative to enhance the auditory signals within the learning environment for children experiencing hearing loss, paying attention to characteristics such as background noise, reverberation time, signal-to-noise ratio, critical auditory distance, the speaker, and intelligibility. Understating the barriers to communication within the educational setting of developing children with hearing disadvantage gives a clearer idea of the need for the educational amplification which will generally improve the learning, listening and academic pursuits of hearing-impaired students. Research has shown that young children in comparison to adults don't listen well in noise [7], and the difficulty children have in understanding words depending on the audibility. Typical hindrances to communication in classrooms that distort the auditory output are reverberation, background noise, distance between sender and receiver, the speaker, and the signal-to-noise ratio.

Each of These Barriers is Described as Below

Reverberation

Reverberation is a reflection of the amount of feedback or echo found in any room; in this instance we refer to classrooms. The more intense the reverberation is, the less will be the speech intelligibility, leading to an unfavorable signal-to-noise ratio. The Reverberation Time (RT) is the time span, in seconds over which sounds take to diminish in a closed room from the instance that the source of the sound has ended and the sound pressure level drops to 60 dB less its starting value [6]. An extended RT allows for the mixing of old and new sounds, impacting the comprehension of the message. Conversely, if the RT is extremely short, sounds will be very low. It was stated that, "the degradation in speech intelligibility due to the reverberation is based on two effects: an overlap masking and a self-masking effect" [4]. The RT suggested by the World Health Organization (WHO) [4] in classrooms is 0.6 seconds.

Background Noise

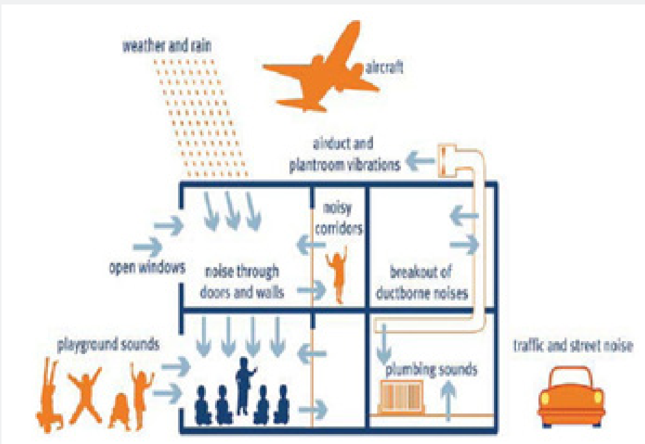

Figure 1: Sources of Background Noise in an Unoccupied Classroom Adapted from Vaughan [9]. This figure depicts the various sources of background noise that children who are hard of hearing must compete with in their classrooms. Noise sources highlighted were from noisy corridors, ventilation systems, plumbing equipment, traffic and other noises from the street, neighbouring classrooms and from playgrounds.

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Background noise level results from extra sounds within the classroom that are not directly related to the acoustic cue of relevance. Background noise is always present from sources such as the chatter of children within the room, movement of chairs and desks, nearby traffic, playing grounds, just to highlight a few. This kind of noise according to Crandell and Smaldino [8] impairs the perception of speech in children particularly the recognition of consonants. The background noise recommended by the World Health Organization (WHO) [4] is 35dB(A) (Figure 1) illuminates the possible sources of background noise in an unoccupied classroom [9].

Distance between sender and receiver

The distance between the teacher and the student or between the hearing-impaired students and their peers as they communicate dictates the volume and clarity with which the information being sent is received and understood. The closer the children with hearing impairment are to the sender (teacher or peers), the more superior the direct sound field is and is barely distorted by the surrounding acoustic barriers, this describes the critical distance [6]. The critical auditory distance as explained by Ling [10] is that distance where the sounds of speech are audible and yet intelligible at the same time. This distance varies and is subject to the acoustic settings of the room. Hearing impaired children possess a shorter critical auditory distance. The direct sound field pressure follows the inverse square law, which means that as distances are doubled from the sound source, the potency of the sound lessens by 6dB [11]. (Figure 2) depicts this law of reduction in sound intensity as the distance between the speaker (Teacher) and the listener (Students) increases. The significant point of interest in classrooms that are occupied is not the exact noise level, instead it's the calculated value of the distance between the wanted speech signal and the unwanted background noise [13].

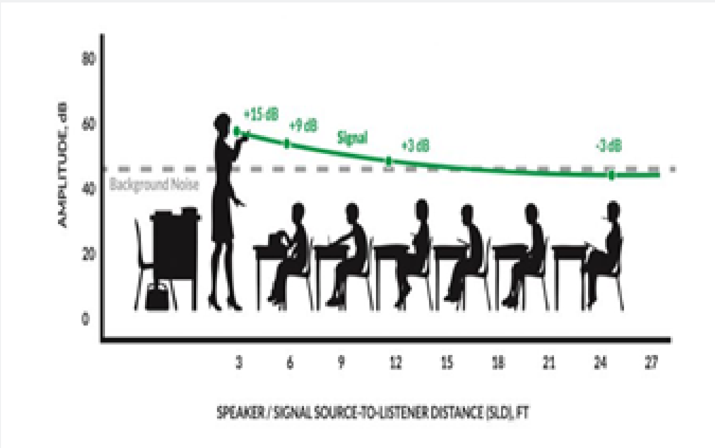

Figure 2: The Inverse Square Law Adapted from the Importance of Acoustic Treatment in K-12 Schools [12]. This figure portrays the effect of the distance between the teacher and the students. Highlighting the principle of the inverse square law which explains that as the distance doubles, the SNR decreases by 6 dB.

The Speaker

The vocal imposition, voice tone, diction, gestures, and other voice qualities all are potential barriers to effective communication within any classroom setting. Teachers or children in the classroom who have good speech and oral attributes will enhance the speech and listening experiences of children with hearing impediments. The greatest factors that impact the intelligibility and perception of speech are the RT and background noise. Teaching surroundings in which the intelligibility is low results in physical and psychological fatigue as children become frustrated and tired from making attempts to comprehend what teachers are saying amidst inadequate acoustics. This leads to detrimental effects on the overall learning ability and development of the child.

Signal-to-noise ratio

The Signal-To-Noise Ratio (SNR) is the ratio that explains the intensity of the speech signal and the value of the noise that the listener is not interested in hearing. A teacher's voice is the signal within the classroom which becomes degraded by various sources of background noise [14]. Sounds that have an impact on the recognition of speech are those with comparable spectral energy of speech [4]. If learning via the mode of listening is to occur, then there needs to be an adequate amount of SNR. Raising the background noise diminishes the SNR, subsequently lowering the speech intelligibility [3]. The suggested SNR for excellent intelligibility in learning spaces should be less than 12dB. The basis of educational amplification has been well documented by research done in educational settings. Research reveals that

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in an effort to achieve learning there needs to be the input of verbal language and the awareness of the verbal language is the basis for acquisition of reading and writing and overall academic attainments [15].

Due to the increasing number of children in the mainstream classroom with hearing disadvantage [16] an acceptable hearing environment is required particularly to ensure that this set of students is included in the learning and listening experience [3]. Having an awareness of the challenges to learning for those children who have hearing abnormalities will influence the need for educational amplification. The overarching aim of amplification in children with hearing impairment is to transmit a signal that can be heard so as to boost the ability of speech recognition and understanding [17]. Technology employed in allowing the acoustic environment of the children with challenges in deciphering the teacher's voice and that of their peers from that of the background or unwanted distracting noise could be needed [8] in our classrooms today. Educational amplification is that technology needed within the classroom setting to augment the options of auditory signals presented to students. Educational amplification is imperative so that all listeners in the classroom benefit from the greatest amount of speech intelligibility [18].

The documented effects of poor acoustics within classrooms and the effects on academic attainments, especially for hearing impaired children, highlights the need for educational amplification in classrooms, notably those of developing countries with higher incidences of hearing impairment than their developed counterparts. The implementation of classroom amplification in developed countries like the United States is said to be increasing. It is surmised that 20,000 units have been installed throughout classrooms in the United States [19]. McCreery et al. [5] found that children who suffer from hearing loss are at a significant risk for substandard speech decipherment in settings with noise and reverberation. However, educational amplification serves to not only be beneficial for those who have hearing impairment but for all students within the classroom. Research done for example by the Mainstream Amplification Resource Room Study (MARRS) project [20] have proven that classroom amplification networks are beneficial to all children within the classroom and not only to those who are hearing-impaired. Sound field amplification systems improves SNR in all areas of the classroom [1].

Even with the most advanced personal assistive hearing devices such as hearing aids, children are still susceptible to environs where noise and the extent of a space impedes the reception of auditory signals. For several children with hearing impairment, personal amplification may be ineffective in giving enough advantages in learning and listening. For this special group of children, technologies designed to enhance learning proficiency in the classroom, especially increasing the SNR is necessary. Much research has over the years focused on the ill effects of unfavorable acoustic settings and the extremely successful benefits that educational amplification has on the developing auditory, language, reading and writing skills of the child with hearing loss. Educational amplification systems, also referred to as hearing assistive technology [21] or technical aids, educational amplification systems minimize the effects of ill-suited acoustic settings on the learning of children who suffer from hearing loss.

Summarized findings of studies carried out in classrooms with sound-field amplification identified that youngsters demonstrated improved attention, reduced behavioral issues, less distractions, active involvement in class activities, and generally a heightened task orientated attitude when compared to youngsters in classrooms without amplification [22]. These solutions include amplification in the form of personal Frequency Modulated (FM) amplification systems or a sound-field system with several speakers positioned in carefully selected places around the classroom. Systems like these may be costly and without proper funding from possibly humanitarian groups or developed countries, schools in many developing countries may find it extremely challenging to implement these methods as part of resources needed to assist the hearing-impaired community of children found dispersed in schools throughout developing countries. Regardless of the school that a child attends, be it for those with disabilities or mainstream school, all learners should have equal learning opportunities with minimal or no barriers (WHO) [23].

Using technology in learning spaces and the cited positive outcomes documented in various research is something worth looking into with more precision and standardization for children on a global scale. The numbers of hearing-impaired children being taught in mainstream school will continue to increase due to the call for inclusion of all children in the educational system with minimum barriers to learning [23], and universal newborn hearing screening [16,19], making it imperative for acoustic environments to be more favorable for learning to all. There is a genuine concern as it relates to this being achieved in developing countries. The subsequent listing below outlines the communication systems available for use in the educational setting in the classrooms of both developing and developed countries.

FM System

System of amplification that is commonly used in classroom settings. It is comprised of a transmitter and a receiver. Its wireless microphone transmitter receives inputs and delivers them through a wireless means to the receiver, that receives this signal amplified. The positive effects of this system have been noted through research in the populations of school-age children in various studies. The desirous effect of fitting a FM unit is to optimised speech audibility and intelligibility, reduce the vocal strain on teachers as well as their audibility and that of the surroundings, diminishes the noise impact, reverberation, and distance. Advantages of this system are that it may be used in

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any age group and for any degree of hearing loss. In addition, it can be placed individually, needs no installation, and allows free movement of both the child and the teacher within the classroom.

There are two kinds of FM systems that have been conventionally used in the educational arena. One is self-contained, worn instead of personal hearing aids and has settings that can be manipulated by the wearer depending on the auditory requirement. This type can be sync with personal hearing aids, used with hearing aids or earbuds or a transducer for bone conduction. The other one is a personal FM system that is put on along with the hearing aids or cochlear implant. This system lacks internal manipulation modes but carries a volume control feature [24]. It is a system that works to amplify the child's listening experience via the delivery of undistorted signal straight from the speaker to the child's hearing aid or cochlear implant. This mode of operation mitigates against the barriers to communication [13]. Each device employs a low-power radio transmitter that is put on by the speaker to transfer FM radio signals to a small receiver utilized by the listener. The operation of this device decreases the impedance to listening and understanding that takes place due to increased or unacceptable distances between a speaker and a listener, particularly the teacher and the student in the classroom setting.

Sound-field technology

Sound-field technology is capable of spreading auditory signals in expansive or small spaces. When employed in classroom spaces, they have a wireless microphone transmitter and accompanying speakers that are either mounted in the ceiling or on walls in different locations of the room. Another option is a desktop sound-field equipment that is mobile and has an associated miniature speaker that maybe placed on the child's desk or on the top of a table. There is sound-field equipment that use FM transferal modalities. Classroom sound-field technology benefits all the students in the classroom as it amplifies the teacher's voice throughout the room [13].

Audio-frequency Induction Loops (AFILs)

In this type of system, wire is connected to an amplifier that converts sound signal into magnetic wave forms. The child's hearing aid is coupled to the hearing loop that must be connected within the classroom itself. The speech from the microphone being worn by the teacher is sent exactly to the hearing aid being worn by the child through the induction coil. The advantage of this networking is that it can be used by one or more than one person at the same time. Furthermore, the child with hearing deficiency has the leeway of wearing the loop around his/her neck and synchronizing it with the FM system. Contrasted to the FM technology, the hearing loop must be installed and sanctioned in accordance to established quality standards.

Visual aids

These are essential in alerting the child with hearing loss via brightly lit signs to important happenings such as dangers, break time or the end of a class session. These may accompany verbal communication as subtitles on monitors placed within the classroom.

Objectives

Review of literature thus far has proven that data re the implementation of educational amplification in developing countries is extremely lacking. WHO [25] projections reveals that in India alone for example, 63 million people have some degree of hearing loss, out of every 1000 children four of them have severe to profound hearing loss, besides, 100,000 newborns are being identified with having hearing inadequacies each year [26]. The steps to educational amplification for these children and the unmentioned numbers of those in other developing countries are wanting. It is on this basis that this paper presents the following objectives as it aims to find out:

1) What the acoustic features are like in classrooms in which hearing impaired children are taught in developing countries.

2) The types of classroom amplification technologies implemented to assist hearing-impaired children.

3) What the current needs are for educational amplification in the classrooms of developing countries.

4) Whether or not protocols are established for ensuring that children with hearing loss have access to a suitable hearing environment for learning and development in these countries.

Hypothesis

The acoustic features of classrooms in which hearing impaired children between the ages of 4 years to 12 years old are taught are unfavorable in developing countries resulting in a dire need for educational amplifications in these settings and for the establishment of protocols allowing hearing impaired children to have a suitable hearing environment for learning.

Methods

This systematic review is detailed according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) protocol which may be viewed at the following web address, https://www.bmj.com/content/339/bmj.b2700. A considerable systematic literature search was carried out looking at articles between years 1990 to 2021. This paper presents a review of academic literature and other sources pertaining to the research title. In the first instance the main source of database PubMed was used to highlight articles of interest and the

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reference lists were then used to obtain other papers of relevance. Other sources included articles found on Google Scholar, and Google search engine. Additionally, published method documents, academic textbooks on audiology and journal articles were used.

Conference abstracts and additional documents not yet published in full were not included in the literature of interest for review. The search was restricted to articles posted in English. Articles both full-text and those with only abstracts were saved to a folder called thesis articles to read through. The topics of articles and abstracts were reviewed for their suitability. Full-text papers were rescreened. After this was done time was spent rereading abstracts as well as full-text articles. Those papers that met the eligibility criteria were saved in a folder marked included article and those that did not meet the criteria for this literature review were saved in a separate folder labelled excluded articles. The researcher was the sole reviewer who screened the titles and abstracts for eligibility. For each piece of writing the following information was extracted where applicable:

a) Recommended criteria for noise levels in the classroom.

b) Types of educational amplification used.

c) Major acoustic variables identified in the classroom.

d) Effect of adverse acoustic environments on children in terms of language, communication, speech intelligibility, and educational attainments.

e) Definitions relating to educational amplifications.

f) Any established acoustic protocols for developing countries and their classrooms.

The Paediatric population formed part of the eligibility criteria as this was the interest group for this study. According to the Commission for the Early Detection of Childhood Hearing Impairment the Paediatric population is an important community in which early detection and intervention thwarts the negative effects of language development and psychosocial ills. In addition, studies which described teachers' opinions on the acoustic environments and policies for making standard classrooms that should maximize on good acoustic environment were deemed eligible for this paper. Those sources that gave information involving schools and amplification programs in developing countries, low-income countries or underdeveloped countries or cities were added as a part of the literature review. Articles that mentioned guidelines or protocols for ensuring classrooms had good acoustic environments were acceptable for this review. Work which discussed classroom amplification technology for university students, and areas outside of the classroom like in the home and canteens for example were not included. Those which carried out studies using animals or insects as their test population were also withdrawn from this review.

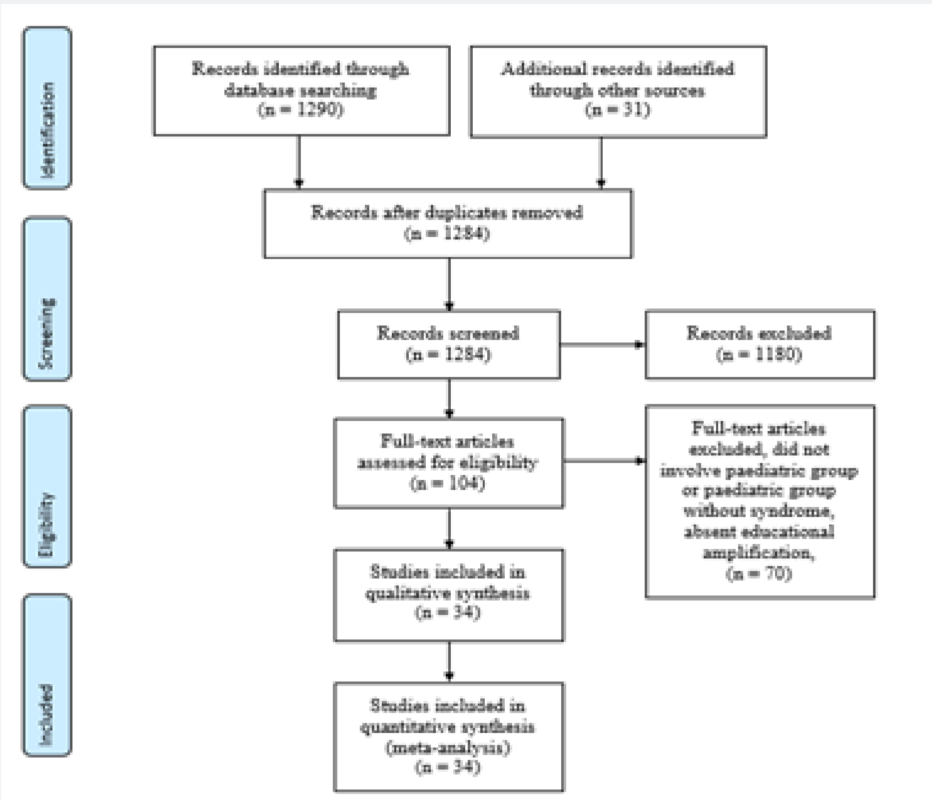

Figure 3: PRISMA flow diagram. Created using a downloadable template [27].

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Moreover, papers which solely discussed classroom amplification for children with syndromic diseases, Autism Spectrum disorder, known behavioral problems and Attention Deficit Disorder were not taken into consideration. Personal amplifications such as conventional hearing aids or cochlear implants used by students were not added to this review document. The search was conducted between December 1, 2021, to January 20, 2022. Keywords used during the search were auditory, classroom acoustics, educational amplification, hearing impaired, communication, listening systems, protocols and developing countries. In all, 1290 articles were identified through database searching, an additional 31 records were obtained from other sources. In total 34 articles detailing varying aspects of educational amplification for children were included in this study after the inclusion and exclusion criteria were applied while screening the published literature. (Figure 3) provides the PRISMA flow diagram adapted from Moher et al. [27] and PRISMA Group.

Result

As it relates to acoustical standards the literature review done by [2] as shown in (Table 1) expresses the suggested range of acoustic standards and the actual range of acoustic standard found in primary school based on National Standards or research done in that field looking at countries from around the world. The results documented are for noise levels in classrooms not occupied, the signal-to-noise ratio in decibel (dB), the Reverberation Time (RT) in seconds, and the speech Transmission Index (STI). It was noted as well that based on National Standards and varying research the range for the background noise levels and reverberation time in unoccupied classroom for children with hearing impairments or language delays were <20-35dBA and <0.3-0.7s respectively. The proposed acoustics for primary school children varied based on age as shown in Mealings' [2] paper. The most recognised identifying consideration of the type of learner in the presence of background noise and reverberation is age [23].

Table 1: Suggested Range for Acoustic Standards for Primary Schools and the Actual Acoustic Values Obtained from Research.

Suggested Range for Acoustic Standards for Primary Schools Based on Research done worldwide					Actual Range for Acoustic Values Found in Primary Schools worldwide			
Group Being Assessed	Noise Level (dBA)	Signal-to-noise Ratio (dB)	Reverberation Time (s)	Speech Transmission Index	Noise Level (dBA)	Signal-to-noise Ratio (dB)	Reverberation Time (s)	Speech Transmission Index
Children with Normal Hearing Worldwide	<25-50	>+8.5 +20	<0.3-0.9	>0.6-0.75	22-70.5	-16 to +23	0.2-1.9	0.3-0.88

Note: The suggested ranges for acoustic standards in primary schools for children with normal hearing based on various research varies and as the table illustrates that the ranges for the different acoustic parameters that are actually found in primary schools differ from that which is suggested by the data. The upper limit of the actual range of noise level was 70.5dBA as compared to the 50 dBA that was suggested. The signal-to-noise ratio that was found ranged from as low as -16 to as high as +23 while the suggested range is +8.5 to+20, the range of reverberation time was relatively the same, the speech transmission index was found to have an upper limit of 0.88 while the suggested one was 0.75.

Ambient noise level and SNR have a different impact within the age range of 5-8 years, noting that those between 7-8 years old accomplish more while being exposed to noise than 5 to 6-year-olds [23]. (Table 2) records the favorable noise levels needed to facilitate speech comprehension in the classroom at different ages. Reverberation has a more considerable impact on speech intelligibility for the individual who has a hearing deficiency when compared to normal hearing individuals [23], than the significance of noise only. To obtain acceptable SNR measures, the ambient noise intensity must be limited. In the South African setting, Van Reenen et al. [23] paper reveals that the actual background noise level is markedly more than that which is proposed by international instructions, therefore making the SNR in the classroom low for this developing country.

A study done in some South African classrooms found that several South African regulations are not consistent as it relates to discussions on the background noise level which was found to be ranging from 35dBA-50dBA. Not much was discussed on the reverberation time for classrooms [6] found that for all the classrooms of the Indian schools studied the listening conditions for children with hearing impairment were not according to recommendations as both the noise level and reverberation time surpassed the suggested maximum levels. They recorded that the average noise level of 37 classrooms while occupied was 63.99dBA (Standard Deviation (SD) of 3.22dBA; range = 56.6-69.8dBA). Only 10.8% of the classrooms exhibited noise level lower than 60 dBA and the majority of the classrooms recorded noise level between 60 and 70dBA.

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Table 2: Favourable Noise Levels that Facilitate Excellent Conditions for Speech Comprehension in Normal Hearing- and Hearing-Impaired Children at Different Ages.

Age in years	Favourable noise level for normal hearing children	Favourable noise level for hearing-impaired children
12	40dBA	<33 dBA
10 to 11	39dBA	None mentioned
6 to 7	28.5dBA	<28.5 dBA

Note: The favourable noise level for children whether they had normal hearing or were hearing-impaired differed according to the age in years. Lower noise levels in decibels, A-weighted measurement, were seen to be more favourable the younger the children are. The table also reveals that the favourable noise level is generally lower for children with hearing impairment.

Unoccupied classrooms noise level was 61.31dBA (SDA =3.59dBA; range 53-66.4dBA), 32.4 % of unoccupied classrooms recorded noise level lower than 60dBA and other classrooms between 60 and 70dBA. The mean SNR in all schools was 11.74dB and 75.74dBA for the teacher speech level. (Table 3) which outlines regulations from studies done re the acoustic design for classrooms for children with hearing impairment from three developing countries. Studies have indicated that the recorded acoustic values of different classrooms even within the same school vary. (Table 4) illustrates the average occupied noise levels, unoccupied noise levels, SNR and RT for selected classrooms that were studied in some developing country. The highest average occupied noise level based on this research was 65.02dBA, that for the unoccupied noise value was 62.2dBA. As it pertains the SNR, the lowest SNR level was 6.8dBA and the shortest reverberation time was 0.77s.

Table 3: Suggested Regulations for the Acoustic Designs of Classrooms in Three Selected Developing Countries.

Country	Sources of Guidelines	Recommended Value for Background Noise in Classrooms	Recommended RT (in seconds) for classrooms
South Africa	Department of Basic Education (2012)	40dBA- 50dBA	0.6-0.7s
	South African National Standards [SANS] (2008)	35dBA	None recommended
India	American Speech Language Hearing Association [ASHA] (2002)	35dBA	<0.4s
Sri Lanka	ASHA (2014)	30-35dB	<0.4s
	American National Standard Institute [28]	35dB	0.6-0.7s

Note: The recommended values for background noise in the three selected countries of South Africa, India and Sri Lanka based on different international standards are essentially the same with the RT ranging between <0.4s to 0.7s among the countries in the table.

Table 4: Average noise levels, SNR and RT of Classrooms Taken from Studies Done in Selected Developing Countries.

Reference	Country	Average occupied noise levels (dBA)	Average unoccupied noise levels (dBA)	SNR (dBA)	RT (s)
Senyasu [29]	Ghana	65.02	47.54	7.17	0.77
Sundaravadhanan et al. [30]	India	62.1	62.2	10.6	2.6
Saravanan et al. [6]	India	63.99	61.31	11.74	1.65 [closed classrooms] 0.93 [opened classrooms]
Reenen, and Plessis [31]	South Africa	_	58.2	6.8	1.01
Pillay, and Vieira [32]	South Africa	61.78	_	<15	_

Note: The table describes what studies have found when that assessed the noise levels, SNR and RT for developing countries Ghana, India, and South Africa. Within the same country classrooms from different Towns were analysed. The highest average occupied noise levels were found in Ghana while one of the areas in South Africa had the lowest average. Ghana however had the lowest average for noise levels in the unoccupied classroom as well as the lowest RT in seconds. Saravanan et al. [6] found in their study an average SNR of 11.74 dBA in classrooms of an Indian city, as seen in the table this was the highest SNR among the countries studied. Not all studies gave average occupied, unoccupied noise levels or the RT.

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Limitations within the Classroom

[16] revealed that deaf and hard of hearing students experienced limitations with being able to participate and interact within the mainstream classroom setting. Results taken from both respondents and observation highlighted the following:

a) Lack of involvement skills of the teacher as some teachers are inexperienced and feel apprehensive about teaching those with hearing needs.

b) Negative attitudes of teachers towards these students and this affects how they are treated by their hearing classmates.

c) Some teachers speak too fast.

d) Poor arrangement of classrooms by teachers.

e) Speech expression was agreed to be the hardest undertaking for the hearing-impaired student.

f) These students are usually engaged in multiple activities as they focus on the teacher, interpreter where present and the task that they must accomplish. This poses difficulty in them participating or responding to questions.

g) They aren't given ample time to process a task and raise their hands to participate.

h) They functioned better in smaller groups.

i) Teacher and interpreter greatly determined the level of student involvement [28-30].

Significance of Location and Sources of Noise

The papers analysed explained what the different locations and likely sources of background noise were in the educational setting as seen in (Table 5). Most of the articles discussed that the utmost cause of background or ambient noise in classrooms was from the children themselves. Study done in Indian schools by [6] recalled that the main noise source in several of the classrooms studied was from electric ceiling fans, some of which were old. Heating, ventilation, and air conditioning systems were significant contributors to background noise in classrooms of developed countries. Several articles agreed that background noise is unfavorable to the developing child with hearing impairment Reenen and Plessis [31], conducted studies on selected schools in South Africa and reported that 36% of the participants acknowledged that excessive sounds contributing to classroom noise at their school was originated from outside. Out of this cohort of respondents, 73% stated that the commonest origin of noise was road traffic, 5% said air traffic, and 7% claiming rail traffic to be their main source of disturbing noise. The other sources were from industry, business, or entertainment.

Table 5: The Location and Likely Sources of Background Noise in classrooms.

Location of Background Noise	Likely Sources of Background Noise
Inside the classroom	Talking children
	Movement of furniture on concrete or tiled flooring.
	Electric ceiling fans
	Lighting equipment
	Heating and air conditioning units.
	Learning devices such as audio-visual or computer gadgets.
Outside of the classroom	Laughter and yelling from neighbouring classrooms or hallways.
	Voices of students during recital activities from nearby classes.
	Noises from other classroom adjustments.
Outside of the building that houses the classroom	Automobile traffic
	Noise from trains and aircrafts.
	Gardening equipment such as lawn mowers or weed whackers.
	Students at play on playing fields.

Note: The locations of the background noise listed within the articles were inside the classroom, outside the classroom and outside the building that houses the classrooms. The likely sources of noise are also shown and differed depending on the locations.

In general, 26% of the schools from the study cited susceptibility to road traffic noise. The various impacts of noise on developing children were outlined in several of the articles. (Figure 4) shows the breakdown of the impacts that were identified and the number of studies that listed these as their findings. Some of the studies mentioned more than one impact. Some of the articles made mention of the variety of amplification systems being used within the educational setting, alluding to the positive impact that these systems have on the overall learning experience and development of children. First-grade children in schools that had amplification being used according to the Trost study as cited in Mckay et al. [22] had a 35% higher score on the

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Dynamic Indicators of Early Literacy Skills tool and scored 21% higher on the Developmental Reading Assessment tool than children who were in classrooms without the use of amplification. Rosenberg et al. as cited by Nelson et al. [13] as cited by found that sound-field amplification systems had beneficial effects on the listening and learning behaviour of students in kindergarten, first and second grade students' general education classrooms.

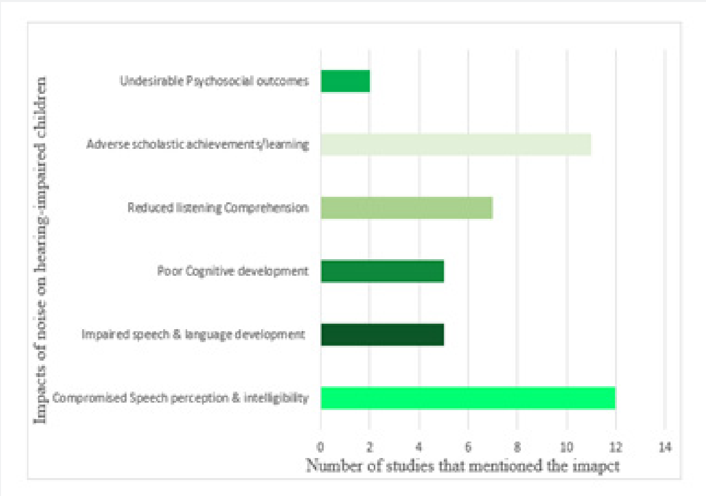

Figure 4: Impacts of Noise on Hearing-impaired Children [33]. This figure illustrates the impacts of noise on hearing impaired children and the number of articles that mentioned the same impacts. Most of the studies mentioned that speech perception and intelligibility were compromised because of background noise. A large amount of the studies suggested as well that adverse scholastic achievements or learning resulted from the impact of noise on hearing-impaired children. Only two of the studies implied that the impact of noise on hearing-impaired children was undesirable psychological outcomes.

The three-year study compared amplified and non-amplified classrooms. Data evaluation highlighted that those students in the classrooms which used amplification had considerable advanced improvement in listening and learning behaviour and skills, with growth developing at a more advanced speed than their classmates who did not use amplification in their classrooms. In addition, the teachers who were in the amplified classrooms indicated advantageous usage of sound-field technology as it related to a reduction in voice strain throughout the day at school. Research also showed that children who aren't candidates for hearing aids, example those with normal hearing or mild hearing loss do benefit from sound-filed systems as they have enhanced speech perception in noise and increased academic performance [32].

There are several merits to educational amplification as outlined in a number of the articles reviewed. Tharpe et al. [22] as cited in Nelson et al. [13] found that primary grades children with normal to mild hearing loss had greater speech perception in noise and bettered classroom performance within the setting of sound-field amplification compared to unamplified classroom conditions. In a study conducted by Nelson et al. [13] on Preschool Teachers' Perception and Use of Hearing Assistive Technology in Educational Settings, most of the respondents perceived that the use of hearing assistive devices led to improved outcomes in academic performance in the child, speech and language development, behaviour, and attention in the classroom. 42% expressed favorable support of the usage of hearing assistive technology in the preschool context. The paper also pointed out that over 70% of the participants communicated that they would suggest the use of sound-field or personal assistive technology in the educational context. Work involving 37 classrooms from four schools in India showed that 64.8% of these schools used hardwire amplification systems while teaching the majority of the lessons [6,33].

A study assessing speech perception done by Anderson and Goldstein as cited in Nelson et al. [13] found that children ages 9 to 12 years old with binaural hearing aid usage had better quality speech perception scores with the use of personal FM systems or desktop sound-field systems comparable to the use of hearing aids only. Research conducted by Nelson et al. [13] highlighted that with the use of sound-field systems in classroom, 94% of respondents saw little or no disadvantages re its effect on student distractibility. 62%-87% stated that there was minimal or no disadvantage to its use on sound quality, comfort with the wearing of the microphone and acoustic feedback or technical difficulties. An insubstantial percentage of 6% differed in their views regarding the disadvantages of sound-field amplification use. Notably as well, few of the articles made mention that

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amplification systems could have interference from nearby magnetic fields when the induction loop was used as well as there can be associated amplification of noise from nearby classrooms [34].

Gains of Educational Amplification

A considerable amount of the studies confirmed that educational amplification had the following gains in children with hearing impairment:

a) Favorable SNR in classrooms,

b) Reduced background noise and reverberation,

c) Better academic achievement,

d) Heightened speech perception or intelligibility,

e) Enriched listening comprehension,

f) Good psychological development,

g) Positive behaviour and attitude,

h) Enhanced speech and language development,

i) Lessened vocal strain for teachers.

Discussion

In general, the body of research on the acoustic features of classrooms in which hearing impaired children are taught between the ages of 4 to 12 years old in developing countries is grossly inadequate. The small volume of data reviewed discovered that for the majority of classrooms the environment is not acoustically favorable for listening and enhanced educational achievement. There is no concrete evidence found which outlines the widespread use of educational amplification in developing countries. Despite limited evidence-based literature, hearing impaired children are exposed on a day-to-day basis to the perils of unfavorable learning environments due to the lack of appropriate listening environments as they occupy classrooms in poor socio-economic countries. There is enough evidence to show that the benefits of educational amplification could augment positive classroom environments thereby enhancing the use of the hearing sense especially for those children who need to be supported with good acoustics in the learning environment.

The favorability of the hearing background of the teaching setting has a significant influence on the learning outcome, educational amplification has notably impacted this outcome based on studies done. Derived from the body of information published re the barriers to communication as well as the need for excellent acoustics in order for the hearing-impaired child to navigate the educational landscape, the recommended international standards for background noise levels, reverberation time, signal-to-noise ratio and distance between the teacher and the student are not ubiquitous in classrooms. It may be inferred based on the literature reviewed those developing countries lack the appropriate checks and balances needed to assess the acoustic state of their classrooms as well as the requisite framework to establish protocols regarding the implementation of assistive learning technologies for their population of hearing-impaired children. From the inception it would have been expected that the environs of classrooms based on scientific data be more favorable for the children with hearing impediments, the analysed literature are however not convincing of such.

Whilst a few studies reported the unacceptable findings of the auditory climate within classrooms of a small number of studied developing countries, these studies barely mentioned the need for interventions such as sound-field amplification, insulation of classrooms so as to dampen the effect of background noise from within and outside of the classroom and to pay keen attention to the shortening of the critical distance between the hearing-impaired student and the teacher. Moreover, none of the studies discussed training sessions with or orientation for teachers pertaining to the use of classroom amplification technologies. Relating to the limitations, this literature review was insufficient in providing a postulatory framework and the creation of models for the state of educational amplification in the classrooms of developing countries. There were inherent biases in this research as the articles analysed were deliberately selected to suit the research topic and the questions this topic posed, also a sole researcher carried out the review of literature. Gaps in the literature limited the researcher's ability to make generalized interpretations on the topic of interest. Based on the sparsity of evidence gathered concerning the needs of educational amplification in classrooms of schools within developing countries it is recommended:

a) That research be carried out on the acoustic features in addition to the necessity for classrooms to be fitted with amplification technology, so as to obtain information on the needs of these vulnerable children within our societies.

b) That clear protocols be outlined that will guide the rehabilitation of classroom spaces for the training of developing children who suffer from hearing loss.

c) That specific state agencies within developing countries collaborate with educational audiologists, teachers, parents, health care providers, and other important stake holders with a view of identifying early both the individual and collective educational needs of children who have hearing loss within the context of the school zone.

d) Evidence shows that many developing countries consist of large numbers of children with hearing disabilities, making them more vulnerable to the challenges associated with this. Therefore, initiatives from developed or resource rich countries are needed to aid intervention in education, an essential component for sustainable growth and development of any society.

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Conclusion

The sense of hearing is of critical importance in classrooms context as children are constantly engaged throughout the school day in listening exercises geared at developing and maximizing their aptitudes. The natural use of this sense is however not easy for hearing-impaired students especially in the presence of unfavorable acoustic parameters. Educational amplification which involves the use of Technical Aids is an economical and known advantageous way of ameliorating the barriers found in the classroom that negatively affect the learning process. Educational amplification delivers an undistorted, increased level message that mitigates against the barriers of communication such as background noise and reverberation. By overcoming communication blockades in the educational setting, the beneficial effects on the developing child with hearing impairment may be obtained.

Educational amplification will not only benefit the hearing impaired but also the normal hearing and teachers by lowering the incidences of vocal strain and thus recurrent health concerns. If it be plausible to minimize and break down barriers to communication and learning within the school context, then all children will be educated [7]. The acoustics of classrooms ought to be developed based on the international guidelines, however this will require a multidisciplinary approach in a bid to ensuring that all children, especially those with hearing impediments have access to a stress-free listening environment where desirable sounds are lounder and speech clearer for their optimal success within the bounds of the learning arena. Installed systems of educational amplification within the classrooms will undoubtedly make this possible. Subsequently, children with hearing disabilities will feel less pressured, fatigued, and discriminated against if they are able to be engulfed in the sea of acquiring knowledge like those with normal hearing. Not only that, but they will also experience improvement in other developmental milestones.

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