Abstract:

Acoustics is the science and technology dealing with sound. Noise is defined as undesirable or unwanted sound. It is our common experience that any mechanical system produces sound which becomes noise when it is undesirable or unwanted. It is known that high noise levels can be annoying or detrimental to health. The noise pollution in our ambient environment is due to the high noise levels coming from sources such as transportation vehicles, machinery, etc. Engineering approaches have to be used to either reduce or control the noise. The engineering methods deal with design of noise control devices such as mufflers, enclosures, vibration isolation mounting, resonators, etc. It is noted that there has not been enough exposure of acoustic and noise control engineering at K-12 level. The scientific and engineering knowledge required to understand and design the various noise control devices can be introduced effectively to K-12 students. Through this exposure they not only get hands-on experience but also obtain sensory acoustic experience of noise reduction. Simplified classroom design and fabrication of devices can be used to illustrate the engineering principles of acoustics and noise control. In addition the students will understand the importance of environmental and engineering impact of noise control. In this paper the authors discuss the relevance of engineering design principles of acoustics and noise control to K-12 students. Also the experience of the authors based on their presentations to the K-12 students will be presented.

Introduction:

We are surrounded with sound. Hearing is a very important means of perception. We are exposed to sound constantly in our homes, neighborhood, city and work place. We experience many times that the sound levels are annoying. In fact when sound becomes undesirable or detrimental to our health it is termed as noise. Noise pollution is an important issue in our industrial society and urban environment. It is important that education about engineering aspects of sound and noise are introduced at K-12 level curriculum so that younger generation when they grow up are equipped with knowledge to control the noise pollution.

Acoustical and Noise Control engineering:

The industrial and urban environment has lead to more and more sound sources that emit higher noise levels. Figure 1 shows that average street traffic produces sound pressure levels about 80 dB. Figure 1 shows the sound pressure levels in various environments that we are exposed to. It is known that noise affects humans physically, psychologically and socially. It can damage hearing, interface with communication, be annoying, cause tiredness and reduce efficiency of the
work. It is not only hearing which can be affected by loud noise but it can also influence blood circulation and cause stress and other effects\(^2\) as shown in figure 2.

![Sound Pressure levels and corresponding pressures of various sound sources](image)

**Fig 1. Sound Pressure levels and corresponding pressures of various sound sources**

Acoustical engineering deals with study of sound generation, propagation and its reception. Noise control engineering deals with systematic studies to eliminate, reduce or use for diagnostics an undesirable acoustical or vibration signal source along the path or at the receiver. It is important to note that noise or vibration could be detrimental to not only humans but also to animals, plants and to mechanical components etc.

A noise control problem is described in terms of control at the source, control along the path and control at the receiver end. The control at the source of noise is more effective because it requires engineering efforts at the design stage itself. The control along the path uses noise control devises such as mufflers, resonators, barriers and enclosures etc. The control at the receiver particularly for humans deals with design of hearing protectors, quiet booths etc.
Fig 2. Sound which influences people via their hearing also has a number of other effects in the body

Relevance of Acoustical and Noise control engineering to K-12 Level:

It is well known that sound plays an important role in everyone’s life and particularly children’s lives. Children relate and respond to sound in a natural way. Music teachers have observed that children grasp subtle nuances in music (sound) with little effort. It can be said that exposure to music at an early age can stimulate and enhance a child’s perception and learning in acoustics.

The inherent enthusiasm and curiosity in children make them actively respond to learn from a variety of sounds. It is interesting to note that the impact and effect of a pleasant and an unpleasant sound can be observed in children by their response and feedback. Children are drawn towards sound producing toys and love to play with them. Some of the feedbacks obtained by one of the authors (M G Prasad) during a presentation to elementary and middle grade students are noted below\textsuperscript{3,4}.
“I like the science of sound because without sound you would not hear anything”
(a 3rd Grade student)

“I liked it (lecture) when you showed us with the sounds as I could understand better”
(a Grade 2 student)

“I liked how you showed the different instrument produces sound”
(a Grade 7 student)

In the high school physics, the topics on sound and vibration deals with pendulum motion, standing waves, resonance and beats etc. Thus we see that although the K-12 level students are interested and also are exposed to science of sound, there has not been enough emphasis on engineering aspects of sound and noise control in their curriculum.

It is important that efforts should be initiated and directed towards engineering aspects of sound, noise and vibration. Some examples are discussed below and suggestions are given about the relevance of these examples to primary, middle and high school levels.

Examples of some engineering noise control devices:

Tuning Fork:

It is a small two-pronged metal device in the shape of a U with a short handle placed on a wooden box with only one end open as shown in figure 3. When struck it produces an almost pure tone, retaining its pitch over a long period of time. One can hear louder sound at the open end.

Helmholtz resonator:

A Helmholtz resonator or Helmholtz oscillator is a container of gas (usually air) with an open hole (or neck or port). A volume of air in and near the open hole vibrates because of the 'springiness' of the air inside. A common example is an empty bottle: the air inside vibrates when you blow across the top, as shown in the Figure 4. Other common examples are small whistles, air in the body of guitar etc.
Muffler:

A muffler (or silencer) is a device used for reducing the amount of noise emitted by an automobile or machine or HVAC equipments. Mufflers are typically installed along the exhaust pipe as part of the exhaust system of an internal combustion engine (of a vehicle, or stationary) or HVAC ducts to reduce its exhaust noise. The muffler accomplishes this with a resonating chamber, which is specifically tuned to cause destructive interference, where sound waves with opposite phase cancel each other out. One of the cut views of the muffler shown in figure 5.1. Typical car and bike mufflers are shown in figure 5.2 and 5.3.

The design and performance analysis of a muffler can be introduced through a simple expansion chamber which is chamber with diameter larger than the inlet pipe as shown in the figure 5.4.
Fig 5.4. Simple Expansion Chamber muffler for noise reduction.

The noise transmission loss (TL) through this muffler is given by,

\[ TL = 10 \log_{10} \left[ 1 + 0.25 (m-1/m)^2 \sin^2 kL \right] \]

Where, \( m = (d_2/d_1)^2 \) and \( k = 2\pi f/c \);

\( k \) = wave number
\( f \) = frequency (Hz)
\( c \) = speed of sound (m/s)
\( L \) = length of expansion chamber (m)
\( m \) = area ratio of muffler and inlet pipe

The maximum performance of expansion chamber occurs when \( kL = (2n-1) \pi /2 \) and minimum performance occurs when \( kL = n \pi \) as shown in figure 5.5.

Fig 5.5 Performance curve of simple expansion chamber muffler
Acoustic Noise Synthesis:

Acoustic Noise Synthesis is the design of a virtual muffler based on the insertion loss model and additionally provides an audio simulation of its noise. The designer is able to experience the sound quality of the output noise and can alter the design of the muffler even before its fabrication. Typical automobile exhaust system without muffler is shown in figure 6.1. Presence of muffler in automobile exhaust system is shown in figure 6.2. (Note: Click the WAVE1., WAVE2. file symbols on the right to listen to the sound output)

![Fig 6.1. Typical automobile exhaust system without muffler element](WAVE1.wav)

![Fig 6.2. Typical automobile with muffler element to suppress the engine noise](WAVE2.wav)

Figure 7.1 and 7.2 shows the system with different tail pipe lengths. (Note: Click the WAVE3., WAVE4. file symbols on the right to listen to the sound output)

![Fig 7.1. Variation of sound output due to shorter tail pipe](WAVE3.wav)

![Fig 7.2. Variation of sound output due to longer tail pipe](WAVE4.wav)
Vibration Absorber:

Vibration and acoustics are inter-coupled. Excessive vibration in machines produces noise. The fan as an example which produce higher noise at higher speeds due to the increase in vibration levels. A common household appliance such as a blender produces higher noise at higher loads due to increase in vibration levels.

To reduce the vibration and in turn noise, there are many engineering techniques available. One of the techniques is by employing vibration isolator we can eliminate the vibration and also the unwanted sound. Rotating equipment (refer figure 8.1) often installed on building structures with large floor spans can excite structural vibration. This vibration some time annoying, damaging or dangerous to equipments or personnel. The engineering (laboratory) model of one of this equipment with high vibration is shown in figure 8.2. The model with vibration isolator to reduce that excessive vibration is shown in figure 8.3. Experimental results of vibration level of rotating machinery with and without vibration isolator is shown in figure 8.4
Fig 8.3. Rotating machinery with vibration isolator to reduce vibration

Fig 8.4. Experimental results of vibration level of rotating machinery with and without vibration isolator

Magic Whistle & Vacuum Hose:

It is known that airflow through uniform diameter tube (pipe) does not produce any acoustic pure tone. However a corrugated tube produces a tone generated by vortices due to discontinuities (cavities). This has application to flexible housing used in vacuum cleaners (see figure 9.1). The typical noise level (frequency vs. dB) of typical uniform diameter tube and corrugated tube are shown in Figure 9.2 and 9.3.
Application to K-12 level:

The example projects described in this paper are Helmholtz resonator, mufflers, acoustic noise synthesis, vibration absorber, tuning fork and corrugated piping. It is important to recognize that type of project needs to match with the various levels in K-12 namely primary, middle and high school. Also the corresponding theory or analysis needs to be developed particularly for high school level.

In the case of Primary School, Helmholtz resonator and tuning fork can be used as an examples since, they are simple to construct and easy to explain. In regard to Middle School, the examples of mufflers and corrugated piping can be used to teach noise control applications. High School level students are exposed to basic knowledge in vibrations in their physics course. Hence, it is appropriate to consider the examples like vibration absorber and acoustic noise synthesis etc., for them.
Conclusions:

Noise pollution is one of the factors that will affect adversely our environment and quality of life. Engineering efforts can substantially contribute to reduction of Noise and Vibration. However, it is not only necessary to emphasize the importance of acoustical and noise control engineering to K-12 students but also to develop education material to teach. Given the natural role of acoustics in our environment, the K-12 level curricula should include the engineering aspects. Although some preliminary material in acoustics and vibration is introduced in K-12 level\(^7\), but that is not sufficient. In this paper authors have provided several simple noise control engineering applications for K-12 level education. Thus the inclusion of topics in acoustics and their engineering applications to noise and vibration control will enhance the K-12 curriculum.

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References:

Biography:

M. G Prasad:

Dr. Marehalli G. (M.G.) Prasad is a professor of Mechanical Engineering and the director of the Noise and Vibration Control Laboratory at Stevens Institute of Technology. He has more than 100 publications and presentations in journals and conference proceedings in the areas of acoustics, noise and vibration. Dr. Prasad has been a consultant in noise control to AT&T, IBM and United Nations Industrial Development organization. He was the general chairman of the National Conference on Noise Control Engineering in 1991. He has chaired several sessions in several national and international conferences of societies such as ASME, INCE, ASA, and IIAV. In professional society activities, Dr. Prasad has been the vice-president of external affairs of the Institute of Noise Control Engineering, USA from 1987-1994. He has been the Metropolitan chapter of ASA during 1987-2004. Also, he has been the chairperson of the technical committees in ASME, INCE and ASEE. Dr. Prasad is a fellow of the American Society of Mechanical Engineers, a fellow of the Acoustical Society of America, a fellow of the Acoustical Society of India, and a board-certified member of the Institute of Noise Control Engineering.

B Rajavel

Mr. B Rajavel is a graduate research student in Noise and Vibration Control Lab, Mechanical Engineering Department at Stevens Institute of Technology, Hoboken, NJ. He received his B.Tech (Automobile Engineering) from Madras Institute of Technology, Anna University, Chennai, India and M.Tech (Mechanical Engineering) from Indian Institute of Technology Madras, India. Prior to joining as a research student he worked as Scientist/Engineer for four years at Aeronautical Development Agency, Ministry of Defense, Govt. of India, where he was involved in design and development of mechanical systems for Light Combat Aircraft (TEJAS).