Sound Qualities: a hands-on student's activity

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Abstract. *This hands-on activity is an attempt at introducing at school sound qualities: sonority, tone and pitch which are closely correlated to physical magnitudes related with natural sensory perceptions.*

Keywords: Sound perception, sound qualities, hands-on activity.

1. Introduction.

One of the relevant examples used in studying mechanical waves in secondary schools is that of sound waves [1]. Amongst the general properties of sound, it is worth highlighting some characteristics that are non-quantifiable in so far as the physical magnitude exists due to the intervention of human sensations in their measurement [2, 3].

However, although these properties are not strict physical magnitudes, they can nevertheless be measured and compared. Such magnitudes are referred to as sound quality and refer to sonority, tone and pitch. Sonority is related to intensity and therefore one can distinguish strong and weak sounds. Tone is related to frequency and therefore helps distinguish between low-frequency and high-frequency sounds, while pitch is related to the shape of the wave and therefore helps distinguish human voice from other voices or distinguish one musical instrument from another.

The A Xunqueira High School in Pontevedra, Spain, designed a set of hands-on experiments in order to introduce these topics and with the aim of change some of these mistaken ideas. The start point was the analysis of noise pollution and its consequences on health [4]. This facilitated the introduction of the sonority concept and its measurement as something significant and closely related to their daily life. To that end, a sound pollution project was initiated for the city of Pontevedra and a noise map of the city was made [5].

Other sound measurements such as tone and pitch were introduced over later years [6]. On this occasion, an interdisciplinary study was carried out, together with the Electronics Department at the High School, that resulted in the manufacture of a filter for electromagnetic waves which enabled oscilloscope visualisation of the harmonics produced by the emulation of the different musical notes of a little electronic organ.

The said harmonics were compared with the common enveloping signal, that can also be seen on the oscilloscope, allowing us to analyse the characteristics of a wave using graphic representation and to calculate the values of amplitude, period and frequency from a given wave equation.

Observation on a computer was also carried out at a later stage. This latter experience meant experimenting with newer resources, developing newer classroom materials, thereby highlighting the relationship between the theoretical and practical aspects of science and their mutual interdependence.

2. Classroom objectives.

The classroom objectives of this hands-on activities are: a) analyse ambient noise pollution in a small city; b) construct an electromagnetic wave filter in the electronics class, c) use an oscilloscope to analyse enveloping frequencies of harmonics that appear for each musical note and the value of their amplitude (such measurements must be made exclusively from oscilloscope data); d) use an oscilloscope and a selective amplifier to study the harmonics generated when emulating instruments with a small electronic organ; and e) undertake the study with at least two instruments and the same musical note (and therefore the same fundamental frequency).

3. Experiments.

3.1. Measurement of sound intensity.

The student is involved in a little research project whose aim is to analyse the sound levels that the inhabitants of Pontevedra city have to withstand. Sonority data were collected from different parts of the city and these were then subject to statistical treatment after which the data were represented on a map of the city. Small groups then contrasted the data collected against municipal norms for sound. The groups then met together to derive conclusions, analyse the noise sources and look into possible solutions.

The aim of this experiment was to provide students with enough knowledge which would enable them to protect their own health and collaborate towards creating a healthier environment. Over the past years, the city of Pontevedra has changed drastically due to the creation of pedestrian streets and the gradual increase of difficulties to flow of traffic in the city. Consequently economic sectors have complained about difficulties for the transportation of goods and tourists.

The above measures have nevertheless produced a huge variation in the noise map of the city. Areas that previously suffered from strong noise pollution have greatly improved their environmental quality. An ongoing present study analyses how noise pollution has evolved after the introduction of the above mentioned changes.

3.2 Analysis of sound from a musical instrument.

The aim here is to study the qualities of the different musical sounds: intensity, tone and pitch.

The earphone output from an electronic organ which emulates the different musical instruments is divided into two signals. One is directly connected to channel 1 of the oscilloscope while the other is connected to channel 2 after first passing through a wave filter. Once the device is setup, the sound output from the many instruments is visualised as an electromagnetic wave on the oscilloscope and this could be done in the physics lab.

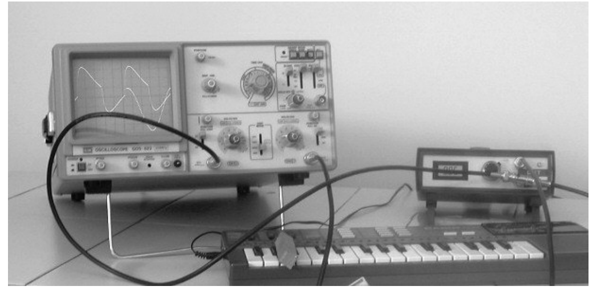

Fig.1. Experimental setup.

The class was divided into little groups. Each group kept a record of the waves observed on the oscilloscope for the different instruments emulated, namely for the piano, flute, violin and the trumpet.

3.2.1. Study of Intensity.

The intensity of sound is related to the wave height on the oscilloscope and at the corresponding scale. Students observe that wave height changes by varying the volume on channel 1.

3.2.2. Study of Tone.

One can identify points that define a periodic repetition (maximum or minimum) on the wave visualised on channel 1, which can be measured on a time scale and is related to the tone of the instrument.

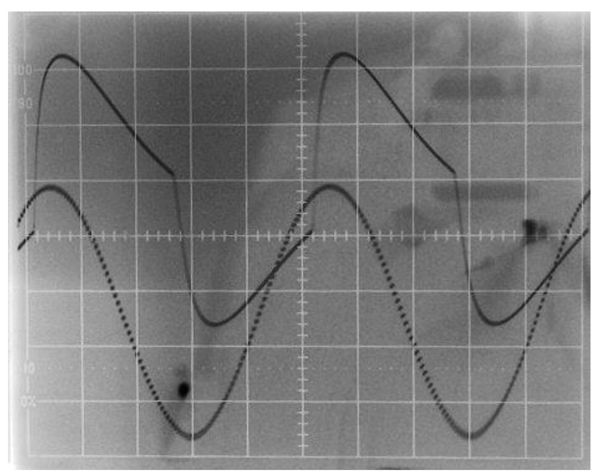

Fig.2. Exit at the oscilloscope for the A note at the electronic organ emulating a flute..

If the initial sound is a musical note such as *A-note* and emulates the flute, one can easily identify the following *A*-note because the frequency in such a case is exactly double the preceding one, thereby producing a periodic wave pattern separated by maximum points (or minimum points) that are half that in the earlier case.

3.2.3. Study of pitch.

An analysis of the graphs obtained shows that the resultant waves are different although the pattern is quite similar and depends on the construction quality of the organ.

One can observe that upon emulating a percussion instrument (or string instrument), the wave gets rapidly muffled while the wave form stays continuous for wind instruments.

3.2.4. Analysis of harmonics generated by a musical instrument.

Many complex periodic waves can be expressed as a combination of simple harmonic movements of periods T, T/2, … and conveniently selected amplitudes. This is called Fourier’s Theorem [7,8]. This theorem also explains sound differences between the different instruments for the same musical note, in spite of the note being produced by the same fundamental frequency. The difference lies in the presence of varying amplitude harmonics relative to each instrument.

The wave filter permits the passage of a set frequency signal. Thus, on channel 2, we can observe the harmonics that contribute the most to the pitch of a musical instrument.

Students become aware that sound quality can be visualised and analysed. Therefore sound quality is no longer abstract and subjective but rather something they can measure and quantify. However, expert musicians do not require an oscilloscope to distinguish between the musical notes nor the pitch of the instruments.

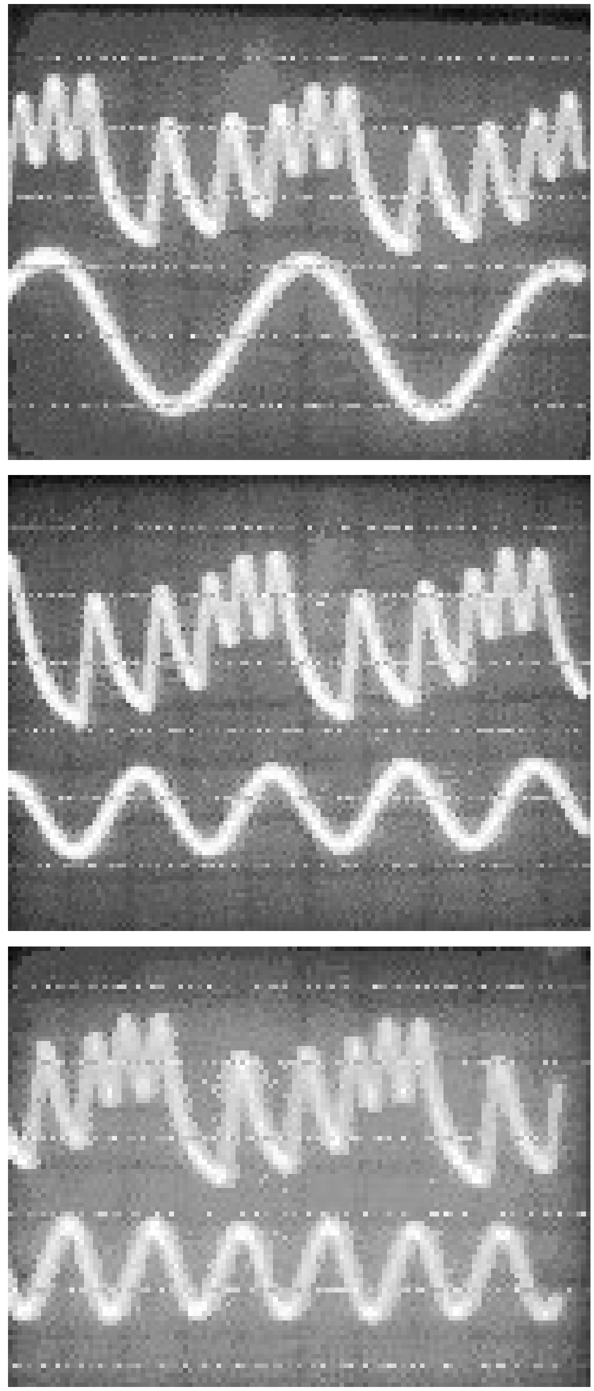

Fig.3 From Top to bottom: Signal produced by an organ on channel 1 and the first, second and third harmonics on channel 2

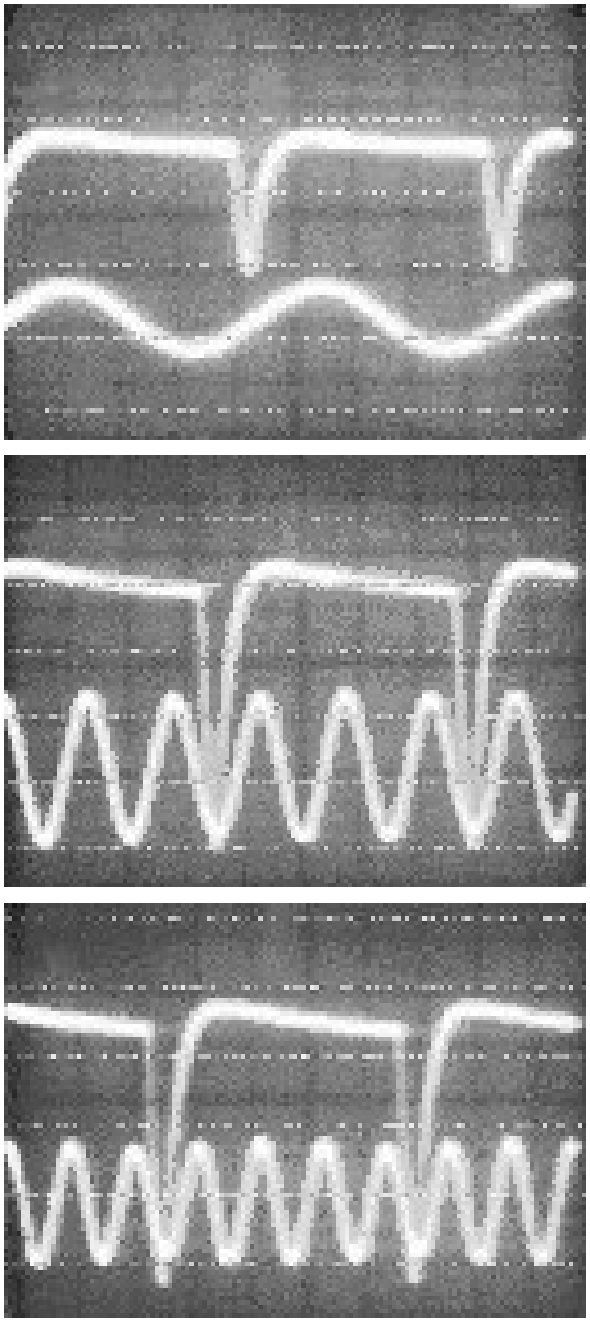

Fig.4. From top to bottom: signal produced by a trumpet on channel 1 and the first, third and fourth harmonics on channel 2

4. Conclusions.

The classroom wave movement study recorded the difficulties experienced by the students during the experimentation. The aim of the experiment was to analyse waves in elastic media such as strings or springs.

In as far as sound is concerned, only sonority could be studied since it enables quantification of a type of sound quality such as intensity. However, this was done using indirect measurements with the inherent problems arising from using a logarithmic scale.

The new hands-on activity enabled a qualitative and quantitative study of sound as a wave movement. The students were able to observe and measure physical magnitudes that they knew existed but were beyond their reach.

Although physics is important, electronics is equally important. The technological subject at school tries to provide basic skills to the student. However, using those skills to construct an electronic device is not always easily achievable. For example, students doing automobile practicals cannot construct an automobile.

The present project has been carried out along similar lines with the handicap that there did not exist any instrument for the students to be inspired on and therefore they had to start from scratch and furthermore obtain a definite result from a set idea.

Both students and teachers were greatly satisfied to note that classroom activities had a bearing in real life and such knowledge would help them to apply the results to their own life situations.

Another advantage is that the student can appreciate that subjects are interrelated and not separate entities. This is an example of a real interdisciplinary approach where two subjects have worked symbiotically towards a common objective and each has benefited from the results of the other.

5. References.

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