THE GUACHARACA AS A TRANSMITTER OF SOUND WAVES: A CROSS-SECTIONAL STUDY APPLIED IN PHYSICS (SOUND), CHEMISTRY (MATERIAL DIFFERENCES) AND SPANISH LANGUAGE (PHONETIC AND LYRICAL)

JOSÉ MANUEL MEJIA REALES, MARBEL LUZ MARTINEZ RODRIGUEZ,
IVÁN ALEXÁNDER CARRILLO MINDIOLA, OVIDIO VILLA CELEDON
josemejia@unicesar.edu.co
Universidad Popular del Cesar
marbelmartinez@unicesar.edu.co
Universidad Popular del Cesar
ivancarrillo@unicesar.edu.co
Universidad Popular del Cesar
ovidiovilla@unicesar.edu.co
Universidad Popular del Cesar

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Summary
The present study presents an analysis of the frequency of the sound waves emitted by the typical instrument of Colombian vallenato music called Guacharaca. For this purpose, the mathematical description of the variation of the frequency of the sound emitted by the guacharaca was carried out in relation to different variables associated with the physical structure of this musical instrument, such as: the separation of the grooves, the number of threads in the trinche, the diameter and the type of material of which the guacharaca is built. as well as the study of the phonetics and lyrics of the songs where the instrument is presented in a solo. This analysis was carried out as part of a cross-sectional study of the courses of basic physics, chemistry and Spanish language; with a sample of thirty eleventh grade students from the I.E. CASD Simón Bolívar de Valledupar, Department of Cesar in Colombia. In order to validate the proposal, a didactic strategy based on the Active Learning Methodology was designed and applied, which allowed, through experimentation, to identify the relevant variables and their relationship with the frequency of the sound emitted by this instrument of Colombian folk music. The efficiency of the implemented didactic strategy was measured using Hake's normalized gain, through the comparison of the results of the diagnostic test with those of the exit test, which evidenced the progress and appropriation of the topics studied by the students.
Keywords: *Guacharaca, vallenato music, sound frequency, materials, active learning.*

1. INTRODUCTION

As we know, the sound wave is a longitudinal mechanical wave that has a frequency whose audible range, for human beings, is from 20Hz to 20,000Hz. The study of the frequency of a sound and in general of an acoustic wave is very important because it is generally associated with the pitch of the sound and in turn with the speed of the wave in the medium in which it propagates; However, the value of sound frequencies also depends, to a large extent, on the way in which the sound is produced, especially if it is a musical instrument. Motivating adolescent students to study these topics in usual educational contexts is not easy, for this reason, in search of didactic strategies for the study of the frequency of some sound waves, it was thought to introduce as a motivating element a musical instrument of Colombian vallenato folk music, in this case, the guacharaca. This is an easily available tool in the region. This, being an idiophone instrument[1] by rubbing, allows several variables to be combined for the study of the sound frequencies it emits.

The work took as its starting point the identification of a possible mathematical relationship between the number of threads of the carving with which the guacharaca is rubbed (which are made of cast iron = cast iron) and the sound frequency emitted, since this varies in relation to the contact material in the rubbing. Since the body of the guacharaca has grooves on which the carving is rubbed, by varying the spacing of the grooves, it is expected that the frequency of the sound will vary since there is less friction interaction; For this reason, the second exercise consisted of finding a possible relationship between this spacing of grooves and the perceived sound frequency. The third exercise was based on the variation of the diameter of the body of the guacharaca to determine whether or not it affected the perceived sound frequency, since the sound studied is the product of the external rubbing of the carving with the guacharaca and not the sound waves inside a tube. The last exercise carried out aimed to analyze the sound frequency perceived when the material of which the guacharaca is constructed by analyzing some mechanical properties of the materials that are rubbed when playing the instrument, for example: that compared to metal, plastic (in this case PVC polyvinyl chloride) has less rigidity and greater elasticity. In addition, the coefficient of thermal expansion of plastic was considered to be 20 times higher than that of metals; also taking into account the fact that the coefficient of kinetic friction between the carving and the different materials varies (cast Iron – Wood 0.485; cast Iron – Steel 0.40; cast Iron – PVC 0.38) [2,3,4]. In the different exercises performed, the trinche is rubbed against the guacharaca with a relatively constant frequency.
At the same time, to carry out the experiments it was important to use a motivating and effective methodology, for this reason the Active Learning Methodology (AMA) was used in this work since it changes the role of the teacher, as the owner of knowledge, to that of counselor, as facilitator, where the result of the experiment acquires a fundamental role. Consequently, students are motivated to work individually and in groups by challenging their preconceptions [5]. This analysis was carried out as part of the basic physics course with thirty eleventh grade students from the CASD Simón Bolívar Educational Institution in Valledupar, Department of Cesar in Colombia.

The Guacharaca
There are several ways of classifying musical instruments, one of them being the one proposed by the musicologists Erich von Hornbostel and Curt Sachs, published in 1914 in their work *Zeitschrift für Ethnologie*, which has the acoustic principles that make the different musical instruments sound [6,7]. These principles classify instruments into: Aerophones, which are instruments that use air as a source of sound and are subdivided into spinal aerophones and free aerophones [6,7]. Chordophones, in which the sound is produced by the vibration of one or more strings in tension and are usually subdivided into four categories according to the mode of excitation: plucked with the fingers or with the help of a plectrum (harps, guitars, bandurrias, lutes, vihuelas, psalteries, harpsichords), rubbed with a bow (violins, etc.), or struck with hammers (pianos, eardrums) [6,7]. Membranophones are those that produce sound through one or more membranes stretched over their corresponding openings (drums)[6,7]. Electrophones are instruments that produce different sounds by producing and varying electrical currents. They are usually subdivided into mechanical-electrical instruments (they mix mechanical elements and electrical elements) and radio-electric instruments (entirely based on electrical oscillations) [6,7]. The fifth group of musical instruments is that of the Idiophones, which are constructed of materials that are naturally sonorous and can produce their sounds in various ways: they are struck, plucked, shaken, rubbed or scraped; The guacharaca belongs to the latter group and is one of the fundamental musical instruments of Colombian vallenato music [8].
Vallenato is a genre of folk music that is frequently performed, listened to and danced by the students of the I.E. CASD Simón Bolívar de Valledupar. It is native to the Caribbean coast, with a greater boom in the province of Padilla (north of the department of Cesar, south of La Guajira and east of Magdalena in Colombia) and is currently recognized, nationally and internationally, for its musical airs: the paseo, the merengue, the puya, the son and the tambora [9]. and a great combination of three cultures: the European accordion, the indigenous guacharaca and the African box. Thanks to

all these expressions, vallenato was declared an intangible and cultural asset of humanity by UNESCO in 2015[10].

The guacharaca is a musical instrument of indigenous origin, it was adopted by the vallenato genre in the mid-twentieth century. Its name derives from a bird – guacharaco – whose song is imitated by its execution. This 'humble' instrument, so called because of its low cost and easy transport, belonging to the family of stems, pieces of reed or calabazos, is part of the musical family of idiophones, because the sound is produced after the vibration of a body (comb or trinche) after being rubbed with the guacharaca.

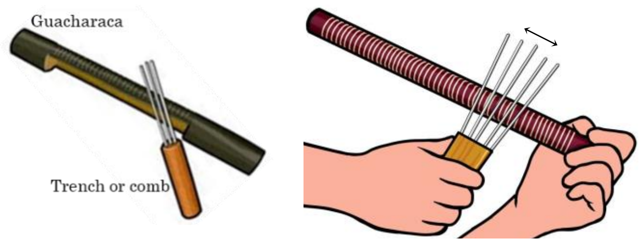

Figure 1. Typical instrument of vallenato music: the guacharaca.

This concave friction musical instrument is composed of two parts: the guacharaca which is made with the stem of "La uva de Lata", which is hollow in the lower central third, and has longitudinal and transverse grooves on the surface (its interior is carved in the shape of a canoe). It typically has a diameter of about 4 cm and a length of about 40 cm and the carving or comb consists of pieces of wire (cast iron) of different lengths that are inserted into a wooden handle. Its total length is normally 26 centimeters, of which 15 centimeters are from the handle and the longest wire is 11 centimeters [8].

This musical instrument, which tries to imitate the song of the guacharaco birds (Orfalis rificauda), is currently a fundamental part of the typical instruments of Colombian vallenato music. To perform it, the part made of tin grape stem is held with one hand, and with the carving, it is gently rubbed with the other hand, in a position at right angles to the grooves. This instrument can achieve a powerful rhythm, and by varying the speed of the rubbing very high frequencies can be obtained as opposed to the low frequencies obtained by slow rubbing.

Depending on the material with which it is constructed and the shape of its grooves, the following types of guacharaca can are distinguished: from a tin grape stem in the form of horizontal grooves, truncated guacharaca from a tin grape stem in the form of horizontal grooves, but on top of these, other oblique grooves, and those made of metal with a series of horizontal and vertical holes (güiro) of different diameters and lengths [8]. In this work, only guacharacas with horizontal grooves were used.

Didactic strategy based on the Active Learning Methodology

The Active Learning Methodology (*AMA*) is one of the methodologies framed within constructivism and valid when the experiment is desired to be the protagonist within the teaching-learning process, since it allows the construction of knowledge through direct observation of the real world. Its structure can be summarized in the following steps, called *PAODS* [5]:

Prediction: about what may happen when a given situation arises.
Activity: Completion of the proposed activity.
Observation: attentive to the results
Discussion: of the results and confrontation with the predictions.
Synthesis: of the concepts or relationships studied between variables (in the best of cases carried out by the students).

At MAA , each student is the central axis in the development of their capacities to develop critique, encourage independent thinking, collaborative work, direct experimental discovery, individual and group work, and debate [5].

Throughout the teaching process there are two groups of students: a control group with which the contents are developed in the traditional way, where the teacher is the one who teaches the chair through master classes, and the experimental group with which the didactic proposal is developed using the *MAA*. In order to establish a comparison of the effectiveness of the proposal between the two groups, it includes a diagnostic evaluation and a final evaluation (similar to the initial one, but not identical). These instruments make it possible to compare the results of the proposal and the progress of the students' knowledge.

Relationship between the frequency of the sound wave emitted by the guacharaca and the number of threads of the trench:

In order to find the average sound frequency emitted by the guacharaca as a function of the number of threads of the carving, keeping the material (arrow reed) constant, 1 cm of separation between the grooves in the guacharaca and using trinches of 1, 2, 3, 4, 5 and 6 threads, an experimental guide of active learning was designed where twenty sounds were produced with a constant frequency of friction. The results of the average sound frequencies for each number of threads in the trinche were plotted and with their trend line and extrapolation the equation that related the variables was found.

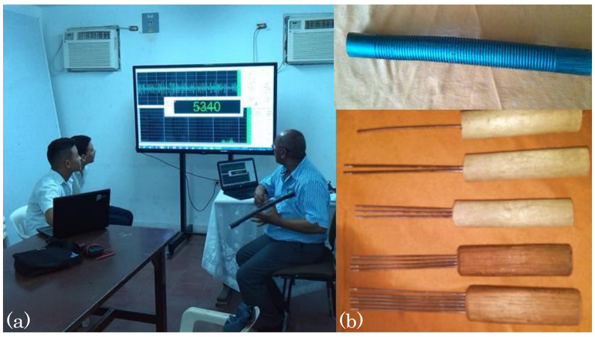

Figure 2. (a) Production of sound with the guacharaca and visualization of the frequency emitted by it. (b) Girdles with different numbers of threads.

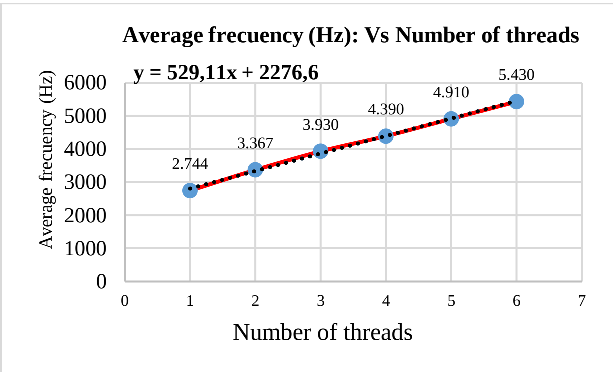

Figure 3. Average Frequency : vs : number of threads in the Guacharaca.

From Figure 3 it can be deduced that between the average sound frequency and the number of threads in the trench there is an approximately increasing linear relationship of slope $529{,}11 \pm 50\ Hz/hilo$.

Relationship between the frequency of the sound wave emitted by the guacharaca and the spacing between grooves with which it was built:

Using guacharacas made of plastic (PVC, polyvinyl chloride) and equal diameter (3/4 in) with separation grooves of 5mm, 10mm, 15mm and 20mm and a five-wire ratchet, twenty sounds were produced with a constant friction frequency, in order to find the average sound frequency emitted by the guacharaca as a function of the spacing between grooves with which it was built.

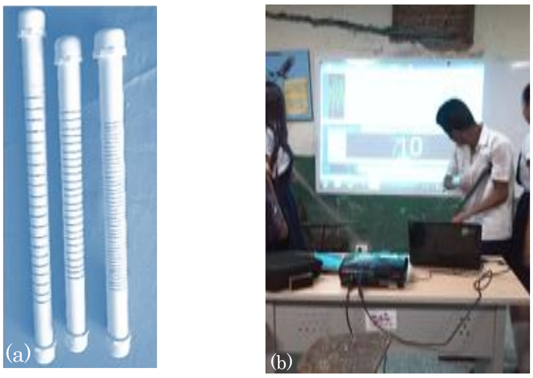

Figure 4. (a) Guacharacas of the same material and with different spacing between grooves; (b) Production of sound with the guacharaca and visualization of the frequency emitted by it.

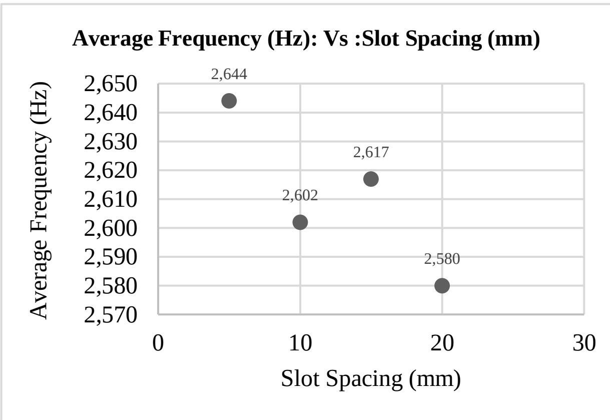

Figure 5. Average Frequency: vs : Slot spacing on the guacharaca.

Thanks to the practice carried out with the students, it was found that as the separation between grooves increases, the sound frequency emitted by the guacharaca is lower and the sound becomes lower, but it was not possible to define a specific and unique relationship between the variables under study, although the experiment was repeated at least 20 times. Probably because the performer didn't achieve a very consistent rubbing frequency.

Relationship between the frequency of the sound wave emitted by the guacharaca and its diameter, keeping the separation between the grooves constant and the same type of material.

Guacharacas made of PVC polyvinyl chloride with diameters of 1/2", 3/4", 1" and 2" are used. With a five-thread carving, sounds are produced by rubbing the carving with approximately constant frequency, the experiment was repeated at least 20 times and the average sound frequency was calculated to observe if there is any variation when changing the diameter of the guacharacas.

Figure 6. (a) Guacharacas made of PVC with different diameters; (b) Production of sound with the guacharaca and visualization of the frequency emitted by it.

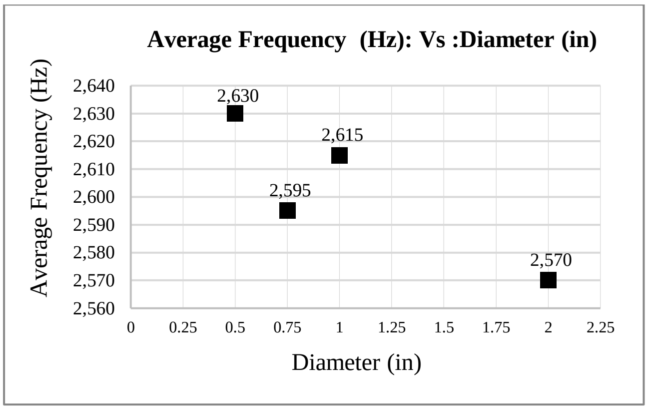

Figure 7. Average Frequency: vs: Diameter of the guacharaca.

In the practice carried out with the students, it was found that, as the diameter of the guacharaca increases, the sound frequency emitted by it decreases slightly and the sound is perceived a little lower, but it was not possible to define a single specific relationship between the variables, although the experiment was repeated at least 20 times. Possibly, because the performer did not achieve a very consistent rubbing frequency.

There is a relationship between the frequency of the sound wave emitted by the guacharaca and the material with which it was built.

Finally, the type of material with which the guacharaca is built is changed, in this case it is used: plastic (PVC, polyvinyl chloride), shaft and stainless steel (Stainless Steel). To find the frequency emitted by the guacharaca, as in the previous experiences, we continue with a laptop, a high-frequency digital oscilloscope, video beam and for the processing of the data we use the Microsoft Excel software®.

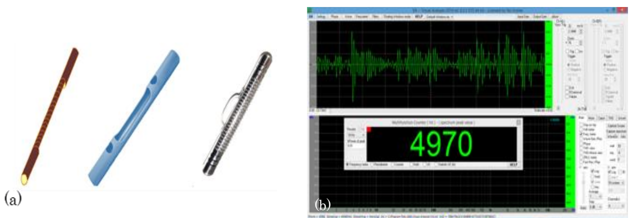

Figure 8: (a) Guacharacas made of arrow cane, PVC plastic and stainless steel; (b) Screenshot of the frequency emitted by one of the guacharacas.

After carrying out the practice with the students following the *MAA* , making twenty measurements in each case, it was found that with the PVC guacharaca the average frequency was Hz, with the Arrow Reed the average frequency was Hz and with the stainless steel (Stainless Steel) the average frequency was Hz. From the above results it is concluded that for the frequency of the sound emitted by the instrument there is a dependence on the material of which it was built and as expected, according to the predictions of the students, the one with the lowest sound frequency was PVC and the one with the highest sound frequency was metallic, being the highest sound. 2.595 ± 10 3.930 ± 10 4.970 ± 10

Validation of the implemented didactic proposal

To validate the teaching-learning process, the initial and final tests were carried out in which basic wave topics were evaluated (types of waves, concept of frequency, sound characteristics, sound instruments), knowledge about the typical instruments of vallenato music and the relationship between the possible variables of construction of the guacharaca and the frequency of the sound emitted by it.

In order to compare the results, the final test was composed of 12 questions, of which 8 inquire about the same topic as the initial test, but with a variation; Four more questions were included with the intention of deepening the concept of the frequency of the sound emitted by the guacharaca by inquiring about some possible knowledge about the relationship between the frequency of the sound and the different construction parameters of the instrument, such as; the spacing of the grooves, the diameter of the guacharaca, the number of threads in the slabs and the material with which the instrument is constructed. Looking at the comparative results between the initial test and the final test shown in Figure 9, it is evident that overall performance improved markedly.

Figure 9 shows the results obtained by the experimental group in the two evaluations:

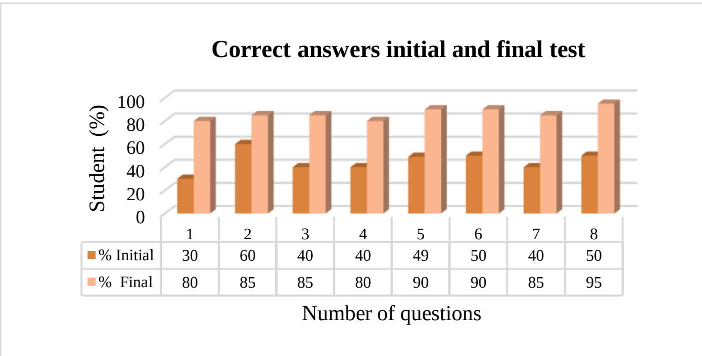

Figure 9. Percentage of correct answers based on the number of questions in the entrance and exit tests.

Figure 10 shows the comparative graph, by student, of the answers obtained in the entrance and exit tests. It clearly shows the significant progress of all students, thus showing that the *MAA* used is efficient.

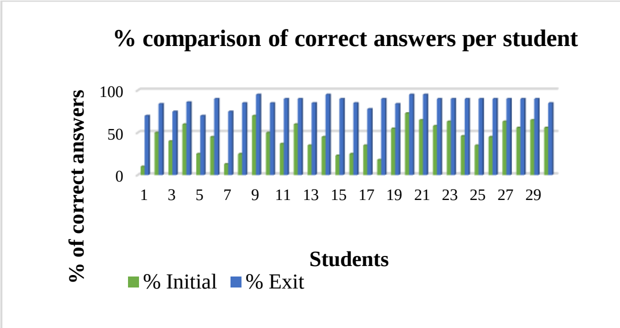

Figure 10: Comparison, by student, of correct answers between the entrance and exit tests.

To quantify this notable advance in the experimental activities carried out, the Hake normalized gain factor (GNH) was calculated[11]. This GNH is normally applied to quantify the conceptual learning of students in the strategy, comparing the results between the initial test and the exit test. This is used to determine the gain rate g in the evaluation of groups in which a didactic component is present. This parameter accounts for the evolution of student learning and avoids the comparison between students who start a course better prepared than others, in addition, it allows to determine if a teaching methodology is efficient with respect to the student's initial knowledge [12].

The g-index is defined as the ratio of the increase in the pre-test (input test) and post-test (exit test) with respect to the maximum possible value. It is determined on the basis of the correct answers obtained in the evaluation instrument used [11]. If $\%<if>$ corresponds to the average percentage of correct answers in the entrance test and $\%<s_f>$ corresponds to the average obtained in the exit test, the relative gain in conceptual learning for each student is determined with the following equation:

$$g = \frac{\%<s_f>-\%<s_i>}{100-\%<s_i>} \qquad (1)$$

The normalized gain obtained in the above equation allows us to categorize the data obtained into three zones as follows: low if , medium if 0.3 and high if $g \leq 0{,}3$ $< g \leq 0{,}7$ $g > 0{,}7$. With the results of the students in the applied tests, it was obtained that 66.6% were located in the high category, 33.3% in the medium category and 0% in the low category.
In turn, by means of the equation:

$$< \bar{g} >= \frac{1}{n}\sum_{i=1}^{n} g_i \qquad (2)$$

The average win rate of all n students was calculated , with *gi* the gain earned by each student using equation (1). With the data obtained, it was found that in this case, placing the average number of students in the upper area of the GNH. The above data numerically corroborate the efficiency of the didactic strategy used.$< \bar{g} >= 0{,}77$

CONCLUSIONS

The Guacharaca, a basic and rustic instrument representative of Colombian folk music from the coastal region, was successfully used by applying the *MAA as a* motivational teaching-learning tool for the study of sound frequency. The efficacy of the proposal was evident when obtaining the average GNH in the high range: $< \bar{g} > = 0{,}77$.
The implementation and development of the experimental active learning guides to determine the frequency of the sound emitted by the guacharaca in relation to the number of threads in the carving, the spacing of the grooves, the diameter and the material with which the guacharaca is built, allowed the students to experimentally verify that: by increasing the number of threads in the carving, the

frequency of the sound emitted by the guacharaca increases linearly, a fact that is in accordance with the laws of mechanics as far as the kinetic frictional force is concerned; since, as there are more threads in the carving, a greater number of molecules will be put into vibration when rubbing with the guacharaca, thus increasing the frequency of the sound waves. On the other hand, it was evident that with increasing the separation of the grooves and their diameter, a decrease in the sound frequency was observed, but it was not possible to establish a single mathematical relationship between the variables, quite possibly because in some cases the performer was not able to maintain the frequency of the rubbing of the carving against the body of the guacharaca constantly; However, the downward trend in both cases is very clear. Finally, it is concluded that the frequency of the sound emitted by the guacharaca is higher in the guacharacas made of metal than in the others, as expected, since compared to metal, PVC has less rigidity and greater elasticity.

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