‘Music': What it means?

This LU is best conducted with the help of music teacher in the school.

Minimum Time Required: 3 sessions of each of minimum 40 minutes

Type of Learning Unit: Laboratory

Pre requisite: Sound as waves, a basic notion of frequencies, ratios and proportions, etc.
question about the alphabet, you may briefly explain that it is as per western musical notes. But they can be ignored for the purpose of the task.
Different discussions can happen at this stage. First and foremost, if the students are

Introduction:

Read following conversation between Rahi and her music teacher.

Teacher: For the annual programme, I need one person from your class to sing national anthem from the stage.

Rahi: All of us like our national anthem. So you can select anyone of us.

Teacher: True. But I will take an audition and select the student who can sing it ‘properly’.

Rahi: What you mean by properly? All of us know the exact words of anthem.

Teacher: Yes. But you don’t have to just ‘recite’ it, you should be able to ‘sing’ it.

Rahi: But all of us also know the tune of the national anthem. So all of us can sing it.

Teacher: Singing is not just knowing the tune. You should sing with exact ‘सुर’.

Rahi: I know the seven सुर. They are सा, रे, ग, म, प, ध, नी.

Teacher: Correct. Singing properly means each sound from your vocal chord should hit correct position of the respective सुर.

Rahi: Correct position? What is that? Are they standing somewhere?

What do you think the teacher is trying to say? Do you understand what she means by ‘correct position’?
Let us take the example of a harmonium.

> Play some keys on harmonium /synthesizer. Preferably select 2-3 keys which are well separated. After discussion, students may conclude that different keys were played or may say that ‘pitch’ of the sound was different.
>
> Next, play the same key but with differing amplitude (volume). This is easy to do on electronic synthesizer. But experienced music teacher can also do it with regular harmonium. Let students discuss what was different in the two cases.
>
> Then ask students:
> You heard it just now. What did you notice?
> Do you know other examples or instruments where you can produce different sound?
>
> Students may give examples of flute, wind chimes, jal tarang etc. In each case ask the respective student to describe the instrument for the benefit of other classmates.
>
> Guide the discussion towards introduction of the term ‘frequency of the sound’. Once the entire group is comfortable with the idea of frequency, proceed to next task.

For the following tasks, we will need a smartphone. There are many smartphone apps which show you frequency of sound played in the vicinity of the phone. We will use one of those apps.

> We have tested this task with two apps ‘gStrings’ and ‘DaTuner Lite’. Any frequency measuring or musical tuning app would work, but we found the ‘DaTuner Lite’ app to be the most responsive to a very wide range of frequencies.

Session-1

Task 0 : Familiarization with the ‘Tuner - DaTuner’ app

Da Tuner App

1) We will be using ‘DaTuner Lite’ app throughout this LU to measure the frequency of different musical notes. When you open the app, the frequency is shown on the bottom left side of the screen. The scale along the left edge shows volume level. Note units of both the quantities.
2) Just to test the app, we will need some volunteers. Take the phone from the teacher. One of you can try saying the vowel ‘आ’ in an extended way and see what frequency gets displayed. Tell the frequency to the entire class and the pass the phone to next group.

The big alphabet displayed in the centre corresponds to the western musical note associated with the frequency which is displayed at the lower left corner. If the students ask question about the alphabet, you may briefly explain that it is as per western musical notes. But they can be ignored for the purpose of the task.
Different discussions can happen at this stage. First and foremost, if the students are not familiar with the units 'Hz' (Hertz) and 'dB' (decibels), there should be some discussion to introduce these units.

Another easy observation would be the natural frequency of girls (~210Hz) and boys (~130Hz) will be different. There can be discussion on the point that female voice naturally has a higher pitch than male voice. Some students may try several different notes themselves. Again there can be discussion on what did he/she exactly change when producing different notes. Which frequency was higher, which was lower etc.

Task 1:
Understanding the relation between different notes on a harmonium

Teacher will play different keys on the harmonium.

For convenience, let us agree to a convention. On the harmonium, you will see a pair of black keys and then a set of three black keys. The white key just before the black pair (first key in the figure) will be called White 1 (W1). As you proceed rightwards from this key, next key will be called Black 1 (B1), the next one is W2 and so on. Note that B3 comes after W4.
Now, note the frequency of the keys in the table below.

Key	**Freq**		**Key**	**Freq**		**Key**	**Freq**	
W1		-----	W8			W15		
B1			B6			B11		
W2			W9			W16		
B2			B7			B12		
W3			W10			W17		
W4			W11			W18		
B3			B8			B13		
W5			W12			W19		
B4			B9			B14		
W6			W13			W20		
B5			B10			B15		
W7			W14			W21		

What patterns do you observe in these frequencies? Write your observations below.

Session-2

Task 2 : Understanding the seven **सुर** for any given scale

In the beginning, Rahi spoke about seven सुर in Indian music. Let us find the relation between सुर and harmonium keys (in a particular scale). Refer to the table above (in Task 1) and note down frequencies of the keys given in table below (in the second row). In the third row of the table, write the ratio of frequency of each key to the frequency of the key W1.

Sur	सा	रे	ग	म	प	ध	नी	सा
Key	W1	W2	W3	W4	W5	W6	W7	W8
Freq.								
Ratio	----							

> Some students may instead choose keys from W8 – W15 and some can take W15-W22. They will realise in case of each octave, they are getting almost same ratios. can all share their ratios and get mean ratio for each सुर.

Harmonium or piano uses pre-defined frequencies which are set to a fixed frequency ratio. This is called ‘equi-tempered scale’. However, one may note that there are other ways of defining scale, which give almost same frequencies. Looking at the decimal ratios in Task 2, one may notice that these ratios can also be expressed as fractions where both numerator and denominator are both integers less than 20.
Write the ratios in that form. The sequence of ratio you get is known as ‘Ptolemaic Sequence’.Task 3 :

Fiinding the frequency of seven **सुर** in any scale

Different scales in music just mean starting your first सुर at another key. Now suppose your first सुर (i.e. सा) is starting with B1 instead of W1. Use the ratios you found above and in the table on the previous page to decide which keys will correspond to other सुर. Here B1 is taken just as an example and you can choose any other key instead of B1,

Sur	सा	रे	ग	म	प	ध	नी	सा
Ratio								
Fre.								
Key								

Play this sequence on harmonium to see if you get similar sequence of sounds as playing W1-W7.

> Extra Task: Some students may like to explore the idea of vocal frequencies further. They may like to match सुर their with that of harmonium. They may try singing a song and see response on the app. Teachers may note that generally vocal frequencies don't exactly match with the frequency of harmonium. Even reasonably good singers can be off by 1-2Hz. For bad singers (ones who we call बेसुरे), they can be off by a larger difference (5-10Hz). Most listeners would not pick up small differences in vocal and instrumental frequencies, but trained singers and good listeners have trained their ears to be more sensitive than most other humans.

Session 3

Task 4: Understanding the working of Jaltarang

Take ceramic bowls / metallic bowls / beakers of different kinds and a measuring cylinder.

Place the 3 bowls / beakers side by side and tap them with a pencil and note down the frequency in each case. Which bowl has the highest frequency?

Description (size and material) of the beaker	Frequency observed

Take the largest beaker, keep adding a fixed amount to water to it (say 25 ml each time) and note the frequency.

Volume of water added	Frequency observed

Is it possible to change the frequency of this bowl/beaker to match that of the smallest bowl/beaker and at what water level will that occur?

What all parameters are important in deciding vibrating frequency of the beaker?

Some students may instead choose keys from W8 – W15 and some can take W15-W22. They will realise in case of each octave, they are getting almost same ratios. can all share their ratios and get mean ratio for each सुर. In this part no water should be added to any bowl / beaker. Discuss what has exactly changed? In first case, one can either change radius of the beaker or one can change thickness of the beaker or one can change material of the beaker. In all these cases you will see clear change in the frequency. In second set, we are just demonstrating that the material of stick also matters, as a compressible material (pencil) will produce different sound as compared to a rigid stick (glass stirrer). The mathematical expression for natural frequency of a beaker is very complex (see below). So it may not be inferred from the data collected. However, one can conclude that for higher frequencies you need
thicker side walls (a),
smaller density of the material of the bowl (ρ),
smaller height of air column inside the bowl (H),
smaller radius of bowl (R),
smaller value of Young's modulus (Y) --need not be discussed.
Natural frequency of a glass shows following relation

$$\nu_0 = \frac{1}{2\pi}\frac{a}{R^2}\sqrt{\frac{3Y}{5\rho}\left(1+\frac{4}{3}\left(\frac{R}{H}\right)^4\right)}$$