Research Article

Understanding Music as a Mathematical Activity through Chrome Music Lab

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Abstract

The paper is an attempt to present some (four) Experiments of Chrome Music Lab in the context of mathematics. The activities suggested in the paper can be used by teacher-students as a pedagogical tool to understand music as a mathematical activity as well as to explore and work on some mathematical concepts as a part of music composition. The activities discussed in the paper can also be worked upon by the general public, parents, mathematics and music enthusiasts, and educators to understand and communicate music as a mathematical activity in an interactive manner.

Keywords: Mathematics, Music, Chrome Music Lab, Pattern, Digital Technology, Inquiry based learning, Visual, Auditory, Kinaesthetic

Introduction

The National Educational Policy 2020 envisions a multidisciplinary, experiential learning and arts integrated approach to curriculum (Ministry of Education, 2020, p. 12). It also advocates for breaking the boundaries between Sciences and Arts. When it comes to mathematics, research and various reports across the globe also emphasise connecting mathematics with interdisciplinary aspects to make learning an enjoyable experience for children. For example: the position paper on teaching of mathematics (NCERT, 2006) emphasises the need for making connections, within mathematics, and between mathematics and other subjects of study. It also emphasises the need to present mathematics as a part of culture through art, architecture and music. The principal and standards for school mathematics by NCTM (2000) on teaching of mathematics also emphasise linking mathematics with other subjects. Among other disciplines, Music is one such area which is enjoyed by learners across all age groups. Everyone enjoys to tap, clap, dance or hum even without any formal knowledge of music. Children can be observed dancing according to some rhythm. According to Shilling (2002) young children come to school with intuitive knowledge of musical patterns and rhythms. Infact, integrating music in a mathematics classroom can be an engaging and joyful experience for children. On the other hand, it is also important that children develop a sense of appreciation towards aesthetical aspects of music; especially in the context of mathematics i.e. they should be able to see or realise the mathematical elements in it and they should be also able to apply mathematical knowledge to understand

and appreciate this form of creativity (music).

Music involves auditory senses. It involves listening, singing, playing instruments but it is also a challenge to describe music in the context of mathematics only through written material. Thus, visualisation and engagement with learners are important to present or describe music as mathematics. Digital technology can ease this process through visualisation. Infact, teaching of interdisciplinary aspects of mathematics is well supported by digital aspects of educational technology such as videos, animations, software, mobile applications, interactive tools etc. Chrome Music Lab is one such example of interactive digital tools which can be used as an educational resource to explore the relationship between music and mathematics. This paper covers four Experiments of Music Lab: Kandinsky, Rhythm, Melody Maker and Song Maker. The paper also suggests some activities related to these Experiments which can be used with inquiry based approaches to understand music as a mathematical activity. As a part of music composition during activity, mathematical concepts can also be taught to children.

Mathematics and Music

Mathematical concepts (elements) in music: The relation between music and mathematics can be represented in various aspects. A musical piece has elements of steady beats, rhythm, tempo, notes, scale, harmony, melody, frequency, time intervals (metre or metrics), cycle, octaves, contrast (high pitch-low pitch) etc. These elements can be explored in the context of patterns, numbers, operations, fractions, multiplication, division, functions etc. Infact, a lot has been written on music-mathematics connections. Dave Benson (2006) presents a comprehensive view of mathematics in music: from trigonometric functions, Fourier analysis, simple integer ratios, scales to symmetry. Konar (2019a, 2019b, 2019c) in a series of article "The Sounds of Music: The Science of Scales", discusses the mathematical aspects in Sound, Western Music and Indian classical music. The three articles explain the science of frequencies, scales (a collection of musical notes), ratio of musical notes, Pythagorean and Equal tempered scale and the mathematical correspondence between Indian classical music and western classical music. However, the activities discussed in this paper are limited to these aspects: Beats (Rhythm) and Melody combination. The activities implicitly involve frequency, pitch, scales and octaves.

Challenges in teaching and communicating mathematical aspects of music: A piece of music or sound can be pleasant to ears, it can be felt or perceived by ears but it can't be seen or visualised directly through eyes. It is a challenge to communicate the mathematics behind rhythm of sounds or combination and timing of musical notes as these are abstract and moreover it depends on the perceiving ability of the listener. In this context, one also needs to introduce such a piece of music for which pattern can be easily recognised or deciphered by the audience. For example: Most of the listeners can talk about a song or a musical composition by humming it or clapping at some critical points, while some music enthusiasts or experts can discuss the same composition in terms of its beat cycle (say, a raga Yaman composition based on teen taal), genre of music, its speed (tempo) etc. One may understand or internalize these ideas with practice (consciously or subconsciously). However, if one tries to communicate these ideas or concepts to children or the common public, it becomes a challenge both for the learner as well as the instructor. Infact, exploring patterns (mathematics) in a musical piece is not as similar as finding colour patterns in a drawing or pattern in arrangement of something concrete like pebbles. Often, people react in a surprised manner when one asks them about the relationship between mathematics and music. The task again becomes challenging when one has to demonstrate and communicate with them about these connections. So, visualisation of music is important and digital technology can bridge this gap between mathematics and music. With the advent of various softwares and digital tools related to music, experimentation with music has become feasible. Thus, one of the rationales behind writing this paper is also to present such activities which can help in communicating and demonstrating music as a mathematical activity to the society.

Chrome Music Lab

Chrome Music Lab is an interactive online resource to play and learn music visually. Chrome Music Lab is a website with a collection of 'Experiments' to create and learn music with hands-on experience. Experiments in Music Lab have been built with freely accessible web technology such as Tone.js, Web Audio API and WebMIDI. These experiments can be played across various devices such as smartphones, tablets and laptops (Chrome Music Lab, n.d.).

Exploring Music Lab to visualise and engage with mathematical concepts: According to Edelson & Johnson,

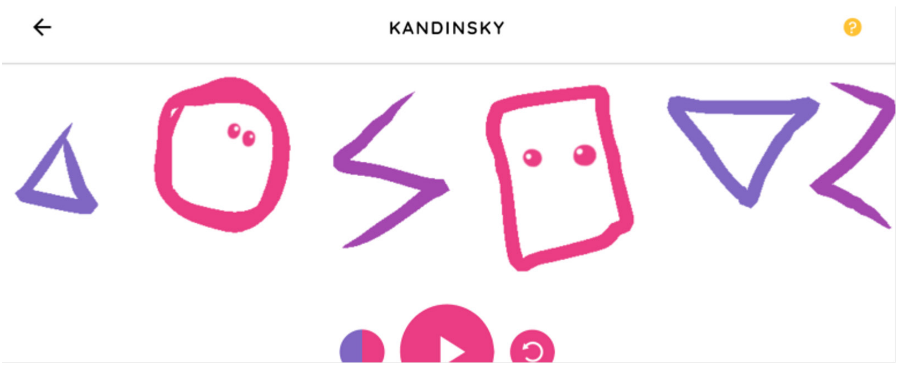
> "In music, children find patterns in the repeated melodies, refrains, or rhythms of a song. Working with patterns enhances children's thinking and reasoning skills, because they must: 1) analyze the pattern to figure out the rule, 2) communicate the rule in words, and 3) predict what will come next in the pattern" (2003, p. 78).

Music Lab explores such possibilities. In Music Lab one can begin with a simple pattern building-understanding exercise and then finally move to composing an instrumental music or song. Children can play with these Music Lab Experiments and create their music and they might not even realise or connect their actions with mathematics. But, engaging them in these Experiments through some activities (which explicitly emphasise mathematical terms and concepts) can help them understand their actions as a 'mathematical activity'. To add, an inquiry based approach can let them develop insights into the mathematical aspect of their Music Lab activities. It will also help them understand and visualize what mathematics lies in making their musical composition. The following section briefly discusses the features and some activities designed for Experiments from Music Lab: Kandinsky, Rhythm, Melody Maker and Song Maker. One can visit Chrome Music Lab at https://musiclab.chromeexperiments.com/ and check out its Experiments.

1. Kandinsky

To begin with, Kandinsky can be used as a warm up activity to make as well as understand patterns. Kandinsky is inspired by Wassily Kandinsky, an artist who considered painting to make music (Chrome Music Lab, n.d.).

Figure-1: Scribbles and drawings on Kandinsky interface



Source: https://musiclab.chromeexperiments.com/Kandinsky/

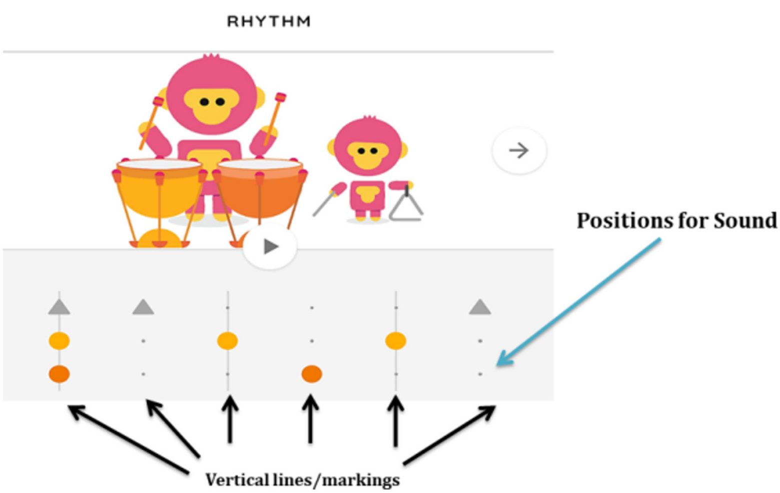
Working: Any scribble or shape on Kandinsky produces a sound. Children (users) are free to scribble or draw any shape on the interface and listen to their composition (https://musiclab.chromeexperiments.com/Kandinsky/). Each shape sounds different from each other (However, it should not be emphasised that shapes have their own sound and music is generated because of shapes. The shapes and drawings are just for fun). When different sounds from the first shape to the last shape get played, it keeps repeating itself and this is an extension of the drawing in a cyclic way. Colour of the shapes can be changed by taping the colour option (left to play button). Sound also changes with change of colour.

Engaging children with patterns: When children scribble or draw their shapes on the interface and tap the play button, they should listen to it for some cycles and understand the pattern. They can be asked to sing or hum the music played to recall the pattern. They can also be asked to scribble again in a way which produces the same pattern. They can also be asked to point or clap at the strongest sound they experience in their drawing (musical composition). Some questions can be posed (without using technical terms): Does the strongest (stressed) sound or a particular sound helps in pattern recognition? What is the role of this sound in pattern generation? They can be asked to listen and compare their music-drawing with their peers and speak out any difference in other's patterns. Let this activity be subjective.

Mathematical significance and relevance: Children are often involved in pattern making or pattern decoding exercises through tactile resources or by drawing various shapes on a surface. But, Kandinsky also involves auditory aspects. The activity can be a good warm up for children to create music and sense auditory patterns through repetitions of sound of their drawing. In Kandinsky Closed figures sound different from nearly closed figures (figure-2). This way, children can learn to create their own sound pattern.

2. Rhythm

Figure-2: Rhythm Interface



Source: https://musiclab.chromeexperiments.com/Rhythm/
Developer: George Michael Brower

Rhythm is a pattern of set of sounds (say, drum beats) in a fixed interval of time. When it repeats for some time, one can decipher the pattern easily. This activity lets one create a rhythm through a combination of three different sounds (percussion or another instrument) by placing them on vertical lines/ markings (equally spaced). One sound or combination of more than one sound produced at one time (on one vertical line) can be counted as one sound. The activity is available in three levels with change of characters and also in the sound quality of drums (percussion) and instruments. The number of vertical lines/markings increases in the other two levels. For example, the cycle repeats itself after 6, 8 and 10 lines in the first, second and third level respectively (tap on the arrow pointing right to move to the other two levels). Characters change in these activities and they play their respective instruments based on the arrangement of sounds made by the user. For example, in this activity (figure), Beats can be created by tapping on the points marked on the six vertical markings. Here, there are a total 18 points (positions) and a particular sound (Grey coloured triangle or Orange circle or Brown Circle) can be placed/

played at maximum 6 positions (in their corresponding rows). If all the points of one vertical marking are occupied - it would sound together.

Steps to play and create rhythm (music):

1. Go to https://musiclab.chromeexperiments.com
2. Tap on Rhythm
3. Tap on the topmost point on any of the six lines. Similarly, tap on the middle point and on the lowermost point of any of these lines.
4. Each point corresponds to the instrument played by the two characters. It also represents the corresponding sound. This way one can check the different sounds on three ordered positions of lines.
5. Select or tap on all of these points or some points and then select the play option.
6. Listen to the music created through 'arrangement of different sounds'.
7. Likewise, one can create different 'patterns' by changing (increasing or decreasing) the number of sounds and also its position.

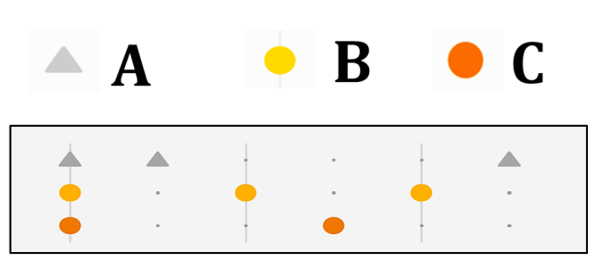
Note: Let the cycle of arrangement of these sounds repeat for some time until you realise or understand its pattern.

How can children understand Rhythm as a mathematical activity?

E. Geist (n.d.) highlights the importance of rhythm (in general) as "Rhythm helps children learn to recognize one-to-one correspondence and to identify and predict distinct patterns" (para. 9). The discussed activity also involves making sense of permutation and combination of three types of sounds, pattern making, symmetry, counting the number of sounds and the position of sounds (cardinal, ordinal and nominal) and spatial thinking (Spatial arrangement of sound on the interface and Symmetry of arrangement/position of sounds). Children can construct their own rules to make it and play. They can identify their rule in terms of their musical pattern. Edelson & Johnson (2003) suggest some pattern building activities (p. 3) through music. Some of these pattern building exercises can be explored with Rhythm in the following ways:

a. Naming or Codifying patterns:

Figure-3: Representation of sounds by letters



Source: https://musiclab.chromeexperiments.com/Rhythm/

In Figure-3 (A snapshot from the activity), Rhythm has been created with 4 grey triangles (sound A) in the first row, 3 yellow circles (sound B) and 1 orange circle (sound C). The positions (dots) are at equal intervals (though it depends on the user/children if they wish to play the sounds A, B and C at equal positions or any position). These different pieces of sound can also be played together. For example, if two positions on a line or all the positions A, B and C in a line are played together then it can be represented using brackets as – (AB) or (BC) or (ABC). A '-' can be used to denote an empty line (no sound played on a line). For this figure the pattern can be written or named as (AB) ABAB (AC). Numerals can also be used. For example: (12)1212(13), 1-2312, (123)-21 (23)12 etc. Corresponding colours (Grey, Yellow, Orange for occupied positions and White for an empty space) can also be used to represent the pattern in colour codes.

b. **Translating the pattern:** In this activity a pattern can be translated from one medium to another; for example, from sound to visual. The Rhythm pattern (figure) can be visualised in the form of gestures of physical movements by children. Each sound A, B and C can correspond to certain physical movements or gestures.

For example:

Table-1: Physical movements and gestures as per rhythm sounds

Sound	Physical movements/gestures
A	Raise left hand
B	Clap
C	Raise right hand
(ABC)	Raise both hands and Clap simultaneously
(AB)	Clap to left side
(BC)	Clap to right side
(AC)	Raise both hands
'-' Empty space	Free your hands

c. **Different elements in pattern:** The above pattern is a three element pattern. Three instruments are played by two characters. Children can be asked to identify the characters from corresponding sounds.

d. **Tracking any changes in Pattern:** Let children listen to patterns and engage them to raise their hand when they sense any change in the pattern. They can also raise their hand at the point of change.

Some additional activities can be suggested for Rhythm:

a. Children can be asked to find out the ratio of their three sounds in one cycle.

For example: What is the ratio of these sounds A, B and C in one cycle?

What is the fraction of sound A used in the composition?

b. Otherwise, they can be asked to create a musical piece where the ratio of three sounds is 1:2:5 (say). For example: What can be the different combinations of this ratio (A: B: C :: 1:2:5)? Play these and check how these combinations sound.

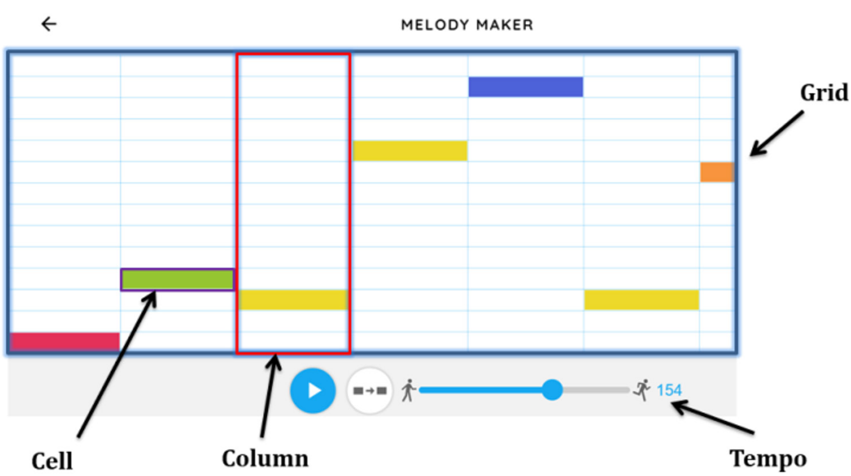
c. Based on the pattern they create, they can be asked to listen to different compositions and tell which pattern they like the most and why? Is there any symmetry in it or not?

d. A student can create a piece of music, and then another student can be asked to find out the respective positions of sounds produced by the two characters. So, by doing this, they can understand the mathematical grammar behind their music – combination and timing of sounds (beats).

e. Children can be asked to investigate position for a particular sound using coordinates and create a rhythm based on some set of coordinates. For example in (a, b) , if a corresponds to the position of vertical line (from left) and b corresponds to the position of point on line/marking (count as 1, 2 or 3 from the bottom of vertical marking), then sounds can also be represented through coordinates.

3. Melody Maker

Figure-4: Melody Maker Interface



Source: https://musiclab.chromeexperiments.com/Melody-Maker/
Developer: Yotam Mann and Eric Rosenbaum

In a song, Melody is the movement from one note to another note. Melody Maker is based on a grid-like structure- a collection of 14 x 8 cells (14 rows and 8 columns) as seen in figure-4. Each cell corresponds to a melody. One can play 14 different sounds in this structure. Sounds vary in pitch as one goes through the lowermost row to the top row. In each column, only one cell can be selected (played) at a time. Cells corresponding to a particular position (row, column) can be identified with a colour. Although there are 14 cells (different sounds), these are represented by 7 colours in an ordered way. One can select some cells at different positions and listen to the melody created. There is an option of switching the sound quality from piano to guitar etc. One can also increase or decrease the speed of the melody using the tempo option. Here, the range of tempo is 70-140 (measured in beats per minute).

Steps to play and create music:

1. Go to https://musiclab.chromeexperiments.com
2. Tap on Melody Maker
3. Tap on any cell in one of the columns to play notes.
4. Tap on some cells in any row.

   (By repeating steps 3 & 4, one can get used to the working of cells)
5. Tap on cells based on some pattern and then click the play button. The melody starts repeating after the last column. One can listen to the pattern.
6. One can increase or decrease the speed (duration) of your music using the Tempo option.

How can children understand Melody Maker as a mathematical activity?

Like Rhythm, this activity also involves permutation and combination of various cells. Arrangement of various cells at different positions also leads to spatial thinking. Children can create their own pattern using coloured cells- musical and colour pattern; and compare with patterns made by their peers. They can change the tempo of their melody piece and understand this action in terms of fraction, multiplication and division. Some activities have been suggested:

a. Pattern Building

- Exercises can be developed based on the pattern exercises discussed for Rhythm.
- Children can be asked to explain the colour pattern and musical pattern (rule) of their melody.
- They can also be asked to create a melody based on a fixed (given) pattern.
- The cells can be played at odd positions, even positions, equal intervals, random intervals.

b. Ratio and proportion:

- Like Rhythm, children can be asked to create melody and find out the ratio of different colours (sounds) generated. They can also be provided with a ratio of colours and asked to make a melody based on this. “Are there multiple ways/ combinations to create melody based on this?" Such questions can be posed to children.

c. Fractions: The concept of fractions can be involved through some questions based on investigation and actions: For example: "What fraction of a particular row is coloured?", "Make a melody where 2/3 of the first row and ¾ of the last row are coloured" etc.

d. Multiplication and Division: Children can be asked to change the tempo by half, one fourth, one third of the current tempo. Likewise, they can be asked to increase or double the tempo. This way they can understand the speed of a melody (musical piece) in context of multiplication and division of tempo. They can also realise that as the tempo increases, the duration of completion of one cycle of arrangement of cells decreases and vice-versa.

e. Identifying a cell through [Row, Column] coordinates: The contrast between sounds of a cell can be investigated through coordinates (without help of graph), especially high pitched and low pitch.

4. Song Maker

Figure-5: Song Maker Interface (A Grid of bar length 3 and 2 Octaves)

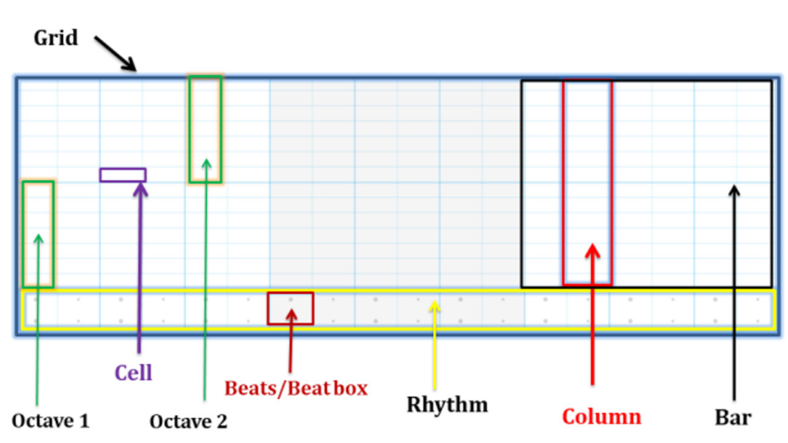
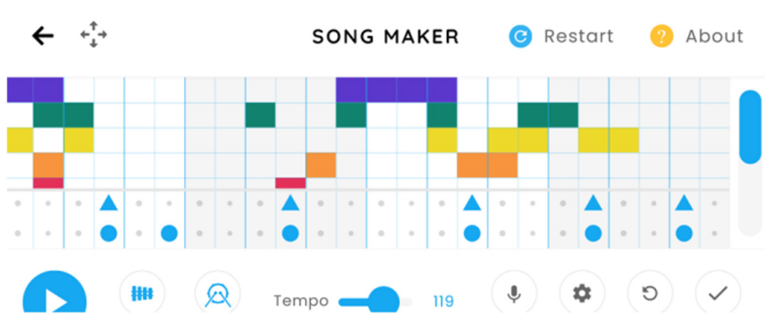


Figure-6: Playing music in Song Maker



Sources: https://musiclab.chromeexperiments.com/Song-Maker/

Song Maker is an extended version of Melody Maker. It has the flexibility to increase the number of grids and columns. Features of rhythm are also present below the grid. While only one cell in a column can be played at a time in Melody Maker, Song Maker allows playing multiple cells in a column at a time. Some practice with Rhythm and Melody Maker will make it easy to play music with Song Maker. One can switch between 5 instruments for melody and 4 instruments for Rhythm. The range of tempo in Song Maker is 40-140 (beats per minute).

Steps to play and create music

The steps are quite similar to Melody Maker, with an addition of Beats below the bar. There is also a flexibility to change the number of cells.

1. Go to https://musiclab.chrome-experiments.com
2. Tap on Song Maker
3. Tap on any cell in one of the columns.
4. Tap on some cells in any row.

   (By repeating steps 3 & 4, you can get used to the working of cells)

5. Tap on the dots below the grid. You can play some sound and generate a rhythm.
6. Make your selection of cells and click the play button. The melody starts repeating after the last column. You can understand its pattern after listening to it for some time.
7. Users can increase or decrease the speed (duration) of your music using the tempo option.
8. Sound effects of the cell and rhythm portion can be changed by tapping on the options beside Tempo.

Additional features: Users can change the grid style and scale and number of notes (cell), number of beats through settings (Figure-7).

Figure-7: Song Maker settings

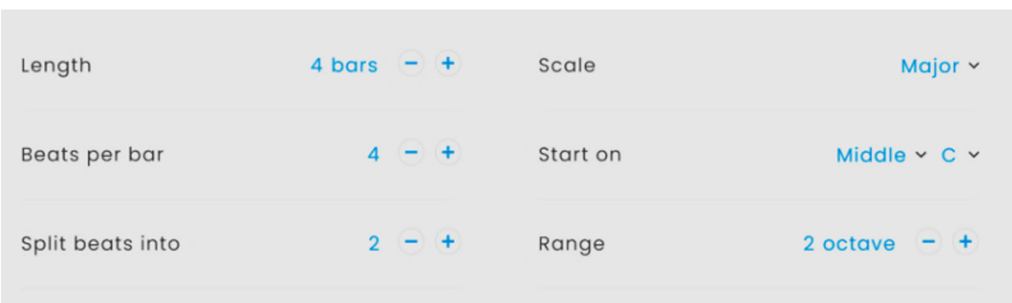


Image Source: https://musiclab.chromeexperiments.com/Song-Maker/

Important features in settings

Length: Length refers to the division of the complete grid into a fixed number of equal parts. For example a length of 4 bars means the whole grid has been divided into 4 equal parts. An alternate arrangement of 2 shaded and 2 unshaded bars can be observed.

'Beats per bar' & 'Beat Split': There are two sounds in a beatbox. These beats (strikes) are used for generating rhythm in Song Maker. In Song Maker, beat actually refers to the beat box (figure 5). The number of beat boxes in a grid depends on the configuration of 'Beat split' and 'Beats per bar' and Length of grid. One can understand the grid configuration by manipulating the settings and observing the changes in grid and bar. For example: If 'Beats per bar' is 4, and 'Beat split' is 2, each bar gets divided into 8 columns and there are a total 8 beat boxes in that bar. Likewise, if the Beat split is 3 with 4 'Beats per bar' and the 'Length' of the grid is 4 bars, then there are a total of 48 (3 x4 x 4) columns in the grid, 12 (3 x 4) columns per bar and one beatbox per column.

The settings options for Scale, Start On and Octave deal with the qualitative aspect of sound and presence of particular musical notes in the grid. For example: by changing the Octave, one can divide the grid vertically into 2-3 parts. If you change the scale, the number of cells/notes in octave changes: Major (7 notes), Pentatonic (5 notes) and Chromatic (12 notes). One can sense the difference in melody and sound of the set of notes/cells in 1st octave and 2nd Octave and in different scales. The sharpness of sound produced by the same cell change when setting gets changed from Low to Middle to High. By changing the 'start on' notes (for example: C to C#), one can observe a pattern in the change of colour of cells as well as sound corresponding to a cell.

How can children understand Song Maker as a mathematical activity?

Song Maker can be treated as a combination of Rhythm and an extended form of Melody Maker. Like Rhythm and Melody Maker, this activity also involves permutation and combination of various notes (cells and colour). Activities based on Ratio-Proportion, Pattern Building, Fractions and Multiplication and Division can again be explored with Song Maker. Song Maker also lets one expand or reduce the size of grid, number of bars and columns according to one's choice, for example: change in the number of columns and cells per bar by changing the number of 'Beats per bar'. 'Beat split' and 'Length'. In addition to these, following activities can also be explored on Song Maker, which can add insights to the conceptual understanding of some topics among children.

a. LCM: Lowest Common Multiple

Using the rhythm option, in Song Maker, children can visualise and understand the concept of LCM. There are two types of sound (Triangular 'T' and Circular 'C') exactly below the melody bar (Figure-8). Depending upon the arrangement (position) of these two sounds; one can explore the concept of LCM.

Figure-8: LCM through occurrence of two different sounds

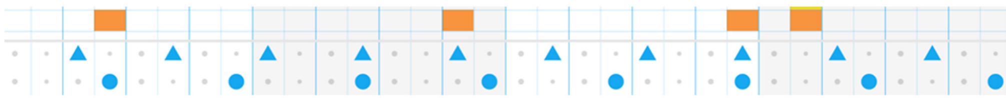


Image Source: https://musiclab.chromeexperiments.com/Song-Maker/

For example: If children make a rule for the occurrence of these two sounds, then they can see these sounds in context of LCM. Suppose, the two beats (say T and C) start at two different positions (count from extreme left of the grid): If T starts from 3rd position and sounds at every third position (interval of three) and C starts at the fourth position and then sounds at every fourth position (interval of four), then they would first sound together at the 12th position (and then sound together again at intervals of 12). In other words, 12 is the minimum distance on the grid where T and C (occurring first time at 3rd and 4th position) meet. Thus, 12 as the LCM of 3 and 4 is justified and visualised through this activity on Song Maker. The beat strip can be extended by changing the parameters in settings and hence, the LCM concept can be explored on Song Maker flexibly for various pairs of numbers.

Note: Experiment Rhythm has a limited number of vertical lines for positioning its sounds in all three levels (6, 8 and 10), so Song Maker can be a better option than Rhythm for visualizing LCM. Interestingly, this can be posed as an inquiry based question for children to find out the pair of numbers for which Rhythm supports generating LCM.

b. Manipulating 'Beat split', 'Beats per bar' and 'Length'

Based on these two activities (a, b), some inquiry based questions can be posed to children.

- Does the LCM of two sounds (T and C) change, when the 'Length' or 'Beats per bar' change?
- Does the number of columns in a bar depend on 'Length'?
- Is the number of columns in the grid or a bar directly proportional to the 'Length'?
- How is the number of columns in a bar dependent on the 'Beats per bar' and Beat Split?
- Can you establish a relationship between the number of columns and 'Beats per bar' and 'Beat split'?

Discussion and Conclusion

The musical activities discussed have been only explored by the author. There is a scope of further testing, experimentation and carrying out educational research with children using activities of Music Lab. However, the focus of the activities discussed is to make children and students aware and realise some mathematical concepts which they can use consciously or subconsciously while making music in daily experiences as well as in Chrome Music Lab. As a part of this, their mathematical learning can also take place. Thus, the significance of these activities also lies in enhancing the mathematical learning of students. Studies (An, Capraro, & Tillman, 2013; An & Tillman, 2015) highlight music-mathematics integrated activities as application to Gardner's multiple intelligence theory (1983, 1993, 1999) and their results also indicate improvement in mathematical achievements of children after participation in music-mathematics integrated activities. Likewise, researchers (An, Zhang, Tillman, Lesser, Siemssen, & Tinajero, 2015; An & Tillman, 2015) have discussed mathematics as a tool in music creation, music as catalyst in mathematics cognition and music as a pedagogical approach. Embedding music activities naturally into children's engagements with mathematics and movements provides a way for children to develop their logic/mathematical and musical/rhythmic intelligences in ways we may not have considered before (Shilling, 2002). Thus, the activities discussed in the paper are relevant in the context of inquiry based learning; kinaesthetic activities, spatial-temporal reasoning and also significant from pedagogical perspective and cognitive development. Designing activities based on Chrome Music Lab's experiments can prove to be an engaging and explorative way of teaching and highlighting a mathematical concept. On the other hand, it can also strengthen peer learning, classroom interactions, and connect with the diversity of learners in the classroom.

Music is a highly social, natural, and developmentally appropriate way to engage even the youngest child in math learning. Music is children's first patterning experience and helps engage them in mathematics even when they don't recognize the activities as mathematics (Geist, E. Geist, & Kuznik, 2012, p. 78).

The activities which have been discussed so far for Music Lab involve basic mathematical concepts upto elementary level. For example: Kandinsky can be used as a starter to engage children with auditory patterns. Rhythm activities let one understand and appreciate the importance of basic elements (beats and timing of its position) in composing a piece of music. Through it one can also understand the role of gaps (time intervals) in music composition. This interactive activity can also be used in the context of inquiry-based learning: asking students to create their own rhythm and investigating questions based on mathematical concepts in their rhythm. In their attempt to repeat the same pattern in these four experiments, children also develop one-to-one correspondence of their drawing, instruments, cells, and colours with corresponding sounds. By manipulating settings in Song Maker, children can understand the proportional relation between columns and beat counts in the grid. Thus, while playing Music Lab through some designed activities, children and students can come across these major elementary concepts: Pattern, One to One correspondence, Making sense of Cardinal, Ordinal and Nominal, Permutation and Combination, Ratio and Proportion, Fractions, Spatial thinking, Coordinate representation, Row-Column representation, Lowest Common multiple, Multiplication

(Double, Triple), Division (Half, One-fourth etc.) and some allied concepts. The educational implication of Music Lab activities also lies in learning elementary mathematical concepts. Apart from these concepts, various allied, basic and high-level concepts can also be included depending on the audience and exploration with Music Lab experiments. Instructors may use the five phase instructional model for music-mathematics integrated lessons proposed by An (2012) and design their activities. Each phase focuses on varying levels of music and mathematics.

Infact, there can be two approaches to use these experiments in Music Lab for teaching mathematical concepts through inquiry-based learning:

1. Asking children, students to create a composition as per their wish and then taking them through their composition to make them realise the mathematical concepts used by them (consciously or subconsciously).
2. Asking children to compose music based on some conditions put by the instructor (for example: the ratio of red notes to yellow notes should be 1:3, only 2/3 of a bar or row can be played in the Melody Maker etc.).

The significance of these activities proposed for Music Lab also lies in the development of visual and auditory senses. Such activities through Music Lab as an interactive digital tool can be used for inquiry based learning in music-mathematics integrated lessons. It will not only engage children musically in learning mathematics, but it will also let them understand and appreciate music as a mathematical activity.

Music Lab Resources:

Chrome Music Lab: https://musiclab.chromeexperiments.com/Song-Maker/

Melody Maker: https://musiclab.chromeexperiments.com/Melody-Maker/

Rhythm https://musiclab.chromeexperiments.com/Rhythm/

Song Maker: https://musiclab.chromeexperiments.com/Song-Maker/

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