International Conference on Islam, Law, and Society (INCOILS) 2022
Confrerence Proceedings

Article

Ethnomathematical Analysis of Piano Playing and Its Implementation in Mathematics Learning

Nala Alfachrudinaa Sa'diyah,[1] Umy Zahroh,[2]

Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung naladinaa@gmail.com, Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung umyzahroh@gmail.com, [2]

ABSTRACT:

Ethnomathematics is a science that is used to understand and express the relationship between culture and mathematics, such as music, so that learning is meaningful and fun. This study aims to describe the concept of ethnomathematics in playing the piano and its relation to mathematics learning materials. The approach used is qualitative with ethnographic method. Data was collected by interviewing two mathematics teachers and two experts in the field of music, and observing piano playing activities and documentation. The data were analyzed through the stages of data reduction, data presentation, and drawing conclusions. Then, the validity check is carried out with the persistence of observers, tringulation, using reference materials, and conducting member checks. The results obtained are: (1) ethnomathematical concepts in piano play, including: counting, locating, measuring, designing, explaining, playing; (2) implementation in mathematics learning: fraction, sets, Cartesian coordinates, relations and functions, and geometric transformations in the form of translation.

Key words: *Ethnomathematic, Piano, Mathematics Learning*

PRELIMINARY

Counting is a part of mathematics that cannot be left out in human daily life. Seconds, minutes, hours, days, months, years are examples of simple and universal calculations. This is in accordance with Alice 's opinion that "Whether we like it or not, mathematics is everywhere" (Wijaya, 2012:vi). Whether we realize it or not, mathematics is often used by the community, a farmer calculating yields, a housewife buying basic necessities that are weighed in certain units, even small children already understand the value of currency and carry out transactions that unconsciously use mathematical concepts. Until this world ends, humans will continue to deal with calculations, namely the scales of good and bad deeds.

Mathematics is a science that deals with or examines abstract forms or structures and the relationships between these things. To be able to understand these structures and relationships, of course, an understanding of the concepts contained in mathematics is needed. Everyone will come

[1] Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung
[2] Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung

into contact with mathematics in all aspects of their activities, whether simple concepts involving subtraction, addition, multiplication, division or more complex concepts. Therefore the mathematical concepts taught must be correct and strong.

Cornelius (Abdurrahman, 2009:253), suggests five reasons for the need for students to learn mathematics, namely: Because mathematics is (1) a clear and logical means of thinking, (2) a means of solving everyday life problems, (3) a means of knowing relationship patterns and generalization of experience, (4) a means to develop creativity, and (5) a means to increase awareness of cultural development. However, it is not uncommon for math to be a disaster for some people because it is considered difficult.

In learning mathematics, if the teacher can connect the material with the students' daily environment, then learning will be more fun and meaningful. Learning by using contextual problems and fun learning is in line with the principle of meaningful learning (Rahmita, 2016: 183). Difficulties will not be felt so much, if students are happy and comfortable in learning. One of the steps that can be used to create meaningful learning is to take advantage of the culture that exists in the student environment.

The field of study used to find the relationship between mathematics and culture is ethnomathematics. The first ethnomathematics was introduced by a Brazilian mathematician in 1977, namely D'Ambrosio. Linguistically, ethnomathematics comes from the prefix ethno, the base word mathema, and the ending tics. Ethno is defined as something very broad that refers to the socio-cultural context, including language, jargon, code, behavior, myths and symbols. Meanwhile, mathema has the meaning of explaining, knowing, understanding and carrying out activities such as coding, measuring, classifying, and concluding. Also, the tics suffix comes from the word techne which has the same meaning as technique. The term ethnomathematics has been used by D'Ambrosio (1985) to mean "the mathematical practices of identiable cultural groups and may be regarded as the study of mathematical ideas found in any cultures," (Rosa and Orey, 2011:35)

According to Albanese (Gunawan, 2019: 19), ethnomathematics is a research program where the focus is on the relationship between mathematics and culture. The culturally specific practices, together with the implied system, constitute ethnomathematics. It is necessary to study these practices and systems in order to describe them, validate them, and use them in education (Barton, 1996:196).

So ethnomathematics can be said to be learning that bridges between culture and education through mathematics. The scope of ethnomathematics includes mathematical ideas and practices that are developed by culture, and can be used by students to understand, articulate, process and use ideas, concepts and practices that are expected to be able to assist in solving problems related to fundamental mathematical activities namely, counting, locating, measuring, designing, playing, explaining (Bishop, 1997).

Based on the thoughts above, the writer focuses on the following problems: 1) how is the ethnomathematics concept in piano playing? 2) how is the implementation of the results of ethnomathematics studies on piano playing in mathematics learning?

RESEARCH METHODS

The approach used in this research is qualitative with the ethnographic method, namely research on the culture of a group in natural conditions, as it is and is not manipulated, so that the condition of the object does not change before being observed, while being observed, or after being observed. The observed phenomenon is the existence of mathematical activities according to Alan J. Bishop, namely counting, measuring, locating, designing, playing, and explaining, in playing the piano.

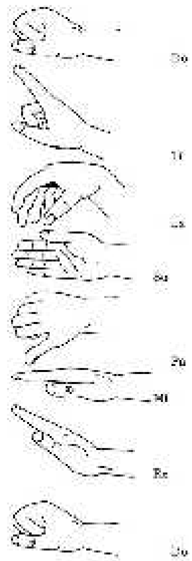
In this study the data obtained were written notes as well as video and audio recordings as well as photographic evidence from interviews with 4 informants, namely, I1 was a high school mathematics teacher, I2 was a junior high school mathematics teacher, while in the field of music, I3 was a musician as well. writer and I4 a choir teacher. The results of observations made when playing music, and data from other sources in the form of books or official documents related to the relationship between music and mathematics. Then the data were analyzed through the stages of data collection, data reduction, data display, and conclusion drawing/verification. Checking the validity with the diligence of observers, triangulation, using reference materials, and conducting member checks.

RESEARCH RESULT

Based on the research that has been done, the following results are obtained.

Table 1. Interview Data

No.	Findings	Interview result
1.	The relationship between mathematics and music	I4: *there's a lot of discussion about music. There is research on numerical intelligence for example. Figural intelligence, etc. Several studies on music and its influence or relation to non-musical intelligence (can be language, numeric, spatial, motor, etc.) depart from the basic understanding and assumption that when a person performs musical activities, he or she is doing brain work in many parts. The parts of the brain that are active when playing music are also used in the other activities mentioned earlier. Now, because these parts are activated and trained, there is a possibility and tendency for an increase in abilities other than music: math, language, motor skills, even emotion. For the type of research I just discussed, there is a lot of research on the effect of music training on mathematical intelligence, the effect of music on learning mathematics, and the like.* *Apart from discussing music and math skills, some research on mathematics and music talks about the intrinsic aspects of music. For example scales, time signatures, etc. There is a lot of discussion here about the mathematical concepts used in music theory calculations. When we learn about the acoustics of sound, for example, there is the use of basic logarithms to determine the frequency of certain notes. Simple comparison calculations to find out the length of the string and the resulting frequency.* *When building a concert hall, for example, there are math-physics of sound calculations to determine the design of the space with the desired acoustics. Counting activities are also of course there. In fact it always happens. Music is very close to the concept of time. For example tempo and beats. Counting one measure containing 4 notes and one measure containing 8 notes must be played at the same time. Calculates the notation value and its duration against other notation values. In addition to calculating the accuracy of the number of notes in one measure, you must be able to ensure that the count is consistent with time.*
2.	Writing Notational Symbols	I4: *so the concept of writing musical notes is the same as Cartesian coordinates using the x-axis horizontally to indicate the duration of the sound and the y-axis vertically to indicate the pitch (high-low pitch).* *writing notation is a representation of sound in the form of visual symbols. Reading notation is the translation of visual symbols into sounds through motor (and cognitive) activities too.* *In simple terms, the numbers 1-7 represent the high and low notes. And this use of number notation is not universal. Western countries do not use numeric notation. In western countries they know the concept of solfa: the use of syllables to represent notations. Just like we do re mi fa so la ti do, but not written using numbers. Use only letter symbols: drmfsltd* *As with block notation, in the end the way of writing is related to convention. Because the conventions for numerical notes are not as extensive as those for musical notes, they are not used in many places.*

		Numerical notation is not used in many places. The pitch level is represented using numbers to help us imagine the pitch. In the Kodaly method, for example, both do re mi fa sol but don't use numbers. they use hand gestures to help students imagine the pitch of the notes. So both mention do re mi etc., but the way of representation varies. Like the following picture.  Picture 1. *Use of Hand Gestures*
3.	Mathematics in *time signatures*	I1: *Yes, in my own opinion, it's like a fraction in mathematics, for example (mathematics) 4/4 means 4 is the quantifier and 4 denominator, if in 4/4 music there are 4 beats with a note value of 1/4 like that, right? If in one bar there are several note values, if you add up the result, it will be worth 4/4, then it is the same as the concept of fraction operations in mathematics.* N4: *To discuss this, let's get to know the concept of time signature a bit.* *The number figure in the time signature shows two things: the top figure is* ***the number of main beats in one measure*** *while the bottom figure is* ***the notation value which represents the main beat.*** *For example: 4/4 time signature means that* ***in one measure there are 4 main beats represented by ¼ notes.***  *Figure 2. Notes Worth 1/4* *While the 2/2 time signature means that* ***in one measure there are 2 main beats represented by half notes.***  *Figure 3. Notes Worth 1/2* *Are they the same? Depends. If we refer to the total notation values that can be entered in one measure, it's probably the same. But in practical terms, it sounds different. This is because the time signature is related to emphasis, accent, as well as grouping.* *From the explanation above, the 4/4 time signature has a basic form like this:*  *Figure 4. Basic Form of Time Signature 4/4*

<table>
<tr><td></td><td></td><td>There are four beats in each measure 1-2-3-4. While the 2/2 time signature has a basic form like this:

Figure 5. Basic Shape of Time Signature 2/2
There are two beats in each measure 1-2 1-2 etc
Well, it would be very different if for example 3/4 and 6/8. In value, these two fractions are equivalent. The sum of the note values is also the same. But the basic form of the two is different.

Figure 6. Basic Form of Time Signature 3/4

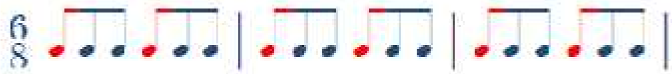



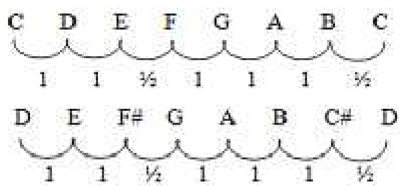
Figure 7. Basic Form of Time Signature 6/8
In the 3/4th measure of the main beat in each measure there are 3. While the 6/8th measure of the main beat there are two in the notation which I colored red. So in conclusion, the concept of fractions in mathematics and music is the same in value, but the musical treatment is different.</td></tr>
<tr><td>4.</td><td>Relations and functions in music</td><td>I1: In my opinion, due to the information previously mentioned that do = D so that between the fundamental tone. If the sheet music is mentioned in a one-to-one correspondence, then the area of origin must have exactly one partner in the opposing area, if what you mentioned Just now there are those who do re mi fa sol la si if you really have 1 exact pair with symbols D, E, etc. then it can be called into a one-to-one correspondence. Because of the terms of the one-to-one correspondence, every pair in the area of origin has 1 partner in the opposing area, not two, can't have more than one pair, must be faithful to the term.</td></tr>
<tr><td>5.</td><td>Translation in music</td><td>

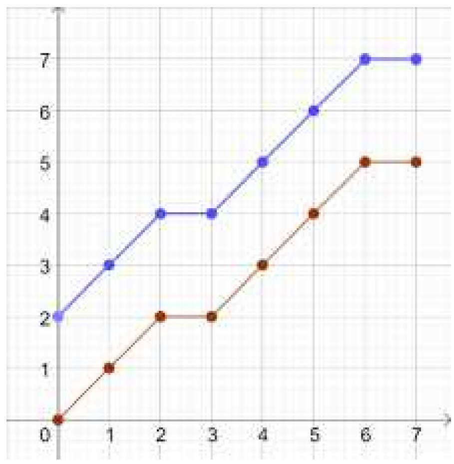
Figure 8. Patterns of the C Major and D Major Scales


Figure 9. Example of C Major Scale Pattern (red color) and D Major (blue color) in Cartesian Coordinates</td></tr>
</table>

	N2: *If you make cartesian coordinates like you did (Figure 9) after the scale has been shifted as far as* $y = 2$ *for example and the pattern remains the same, then you can enter into a geometric transformation in the form of a translation.* N4: *Yes, that's about it. The distance between notes is known as the interval. This interval will be the basis for the development of various other concepts such as harmony, including chord formation, now in chords there are names for chord quality: Major, minor, augmented, diminished, and many more. Then the notes are sounded together and also the formation of melodic grooves, etc.*

Table 2. Observation Results with Participants Playing the Piano

No.	Observed aspect	Appearance Yes	Appearance No	Information
1.	There is a mathematical activity in the form of *counting* in playing the piano.	√		When playing the piano, the participants carried out *counting activities,* namely playing the notes according to the number of beats and the value of the notes based on the *time signature,* as well as performing fractional operations, and playing according to the tempo written on the score.
2.	There is a mathematical activity in the form of *locating* in playing the piano.	√		Aligning the right hand with the left hand when playing the piano, reading musical notes written with an up and down groove
3.	There is a mathematical activity in the form of *measuring* in playing the piano	√		Estimates the high-low distance between one note and the next note, and estimates the time by determining the duration based on the value of the notes and their beats to match the tempo.
4.	There is a mathematical activity in the form of *designing* in playing the piano		√	The musical scores played by the participants were the result of design, in the form of sound representations in the form of symbols, but at that time the participants only played the existing scores, there was no writing activity before.
5.	There is a mathematical activity in the form of *explaining* the piano game	√		Participants playing the piano by reading sheet music (block notation) are then represented as a series of tones that sound, this includes *explaining activities, in the* form of *symbolic explaining.*
6.	There is a mathematical activity in the form of *playing* the piano game	√		Participants carry out *playing activities in the* form of *procedures,* namely initially learning the written notes and then performing certain actions, such as reading each note as it is played. As well as *rule-bound activity* , which is playing notes with certain rules. In addition, there is *imagined reality* , in which participants play the piano by imagining the atmosphere contained in the musical composition

ANALYSIS

Ethnomathematics Concepts in Piano Playing

1. ***Counting***

You may have noticed that the time signature looks a little like a **fraction in arithmetic**. Filling up measures feels a little like finding equivalent fractions, too. In "four four time", for example, there are four beats in a measure and a quarter note gets one beat. So four quarter notes would fill up one measure. But so would any other combination of notes that equals four quarters: one whole, two halves, one half plus two quarters, and so on (Jones, 2007: 35).

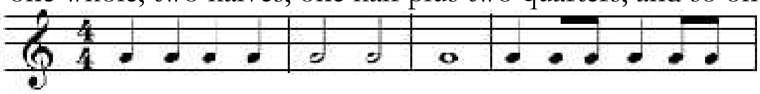


Figure 10. Example *of Time Signature* 4/4

For example, in Figure 10, 4/4 means that there are 4 beats with one beat representing the note value 1/4. In the first measure, it can be seen that there are 4 notes worth 1/4, but in the second measure, there are only 2 notes worth 1/2. A note worth 1/2 is equivalent to 4 notes worth 1/4. This applies to the next bar. So, it can be concluded that the 4/4 sign means that in one measure there are 4 notes worth 1/4 or a combination of notes that have the same value.

2. ***Locating***

Music may be defined as organized pitches occurring in time. Notation must take into account the two dimensions, pitch and time. These are represented graphically on manuscript, or musical writing, paper by a set of conventional symbols using two axes: +; the passage of time is shown on the horizontal axis from left to right →,while the relative position of pitches is represented on the vertical axis:⇕ (Jones, 2007:11). Basically the writing system of beam notation is the same as Cartesian coordinates. The *x* - axis shows the duration of the sound, while the *y -axis* shows the high and low of a tone.

3. ***Measuring***

In one musical activity, there are several mathematical activities that are unconsciously carried out at once. As an example of the concept of time signature. In addition to counting activities, in time signatures there is the concept of measuring or measurement of time. This can be seen from the use of the length of note which is inseparable from the concept of time signature, beats and tempo.

Time signature will determine how many beats are in each measure and the value of notes per beats, while beats are used to measure the length or duration of a tone expressed by length of note, and to find out how long a beat is, a tempo is needed. To find out the duration of the written note, you look at the tempo and the time signature and then see that the note looks like. To find out exactly how many beats it takes, you must know the time signature. And to find out how long a beat is, you need to know the tempo (Jones, 2007:28-31).

In addition to measuring time, playing the piano also involves measuring pitch distance. The distance between notes is called interval. The smallest intervals are half steps (semi-tones) and whole steps (tones), covering the distance of the notes on the stave line. The distance between two tones is termed an interval. The smallest intervals are those of the half and whole step; these occur between adjacent letter names on the staff. On the white keys of the piano there is a half step between E-F and B-C; between all of the other letters there is a whole step (Jones, 2007:31).

4. ***Designing***

In line with designing activities which are more towards the idea of a form, writing notation in music is also an abstract idea of pitch. This is similar to the concept of numbers in mathematics which are a form of an idea. For example, the shape of the number one is "1" which is the conception of the predecessors and has been agreed upon and used today. According to the mathematical view that number is an abstraction, namely a conception or human thought that only exists in the human mind itself (Komariah, 2013: 87).

5. ***Explaining***

Based on fundamental mathematical activities according to Bishop, the notational symbols written on scores are a form of communication that aims to provide an explanation, namely in the form of a symbolic explaining. A score is like a story transcript written using certain symbols. Not only does it contain tone notation symbols and other information in the previous discussion, but there are symbols that explain how the series of tones should be played, called expression marks, including: tempo information (as a determinant of how fast or slow the song is played), dynamics (used to showing emotions or feelings in the song), as well as articulation (the way the melody is played). When a pianist (piano player) plays music according to what is written in the sheet music, and can create a feel for the musical composition, then he has carried out symbolic explaining activities as well as story explanation, namely representing symbols into sounds that contain certain meanings.

6. ***Playing***

Playing the piano is basically an activity of playing as well as explaining, that is, representing the results of designing in the form of notations written into sound, with the rules for counting, locating, and measuring.

Implementation of Ethnomatematics Study Results on Piano Playing in Mathematics Learning

1. **Fraction Count Operations**

In music there is the term time signature, which is a fraction that is placed at the beginning of the score, which means that the numerator represents the number of beats in each measure, while the denominator indicates the value of the note representing one beat. In Figure 10, 4/4 means that there are 4 beats with one beat representing the value of the 1/4 note. In the first measure, it can be seen that there are 4 notes worth 1/4, but in the second measure, there are only 2 notes worth 1/2. 2 notes worth 1/2 is equivalent to 4 notes worth 1/4. This applies to the next bar. For example, the fourth measure consists of notes $\frac{1}{4}+\frac{1}{8}+\frac{1}{8}+\frac{1}{4}+\frac{1}{8}+\frac{1}{8}=\frac{8}{8}=\frac{4}{4}$. So, it can be concluded that the 4/4 sign means that in one measure there are 4 notes worth 1/4 or a combination of notes that have the same value.

2. **Set**

In music there is the term scale which is composed of 7 notes. Let P be the set of notes on the C scale, namely P = {C, D, E, F, G, A, B}, while Q is the set of notes on the D scale, namely Q = {D, E, F#, G, A B C#}. The venn diagram of the set of scales C and D is as follows.

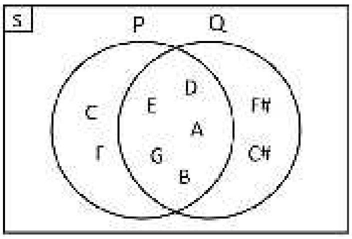


Figure 11. Venn Diagrams Related to Scales

In Figure 11 it is known that $P \cap Q = \{D, E, G, A, B\}$. So, the same notes in the C and D scales are D, E, G, A, B.

3. Cartesian Coordinates

Mathematically the arrangement of notes can be described in Cartesian coordinates as follows.

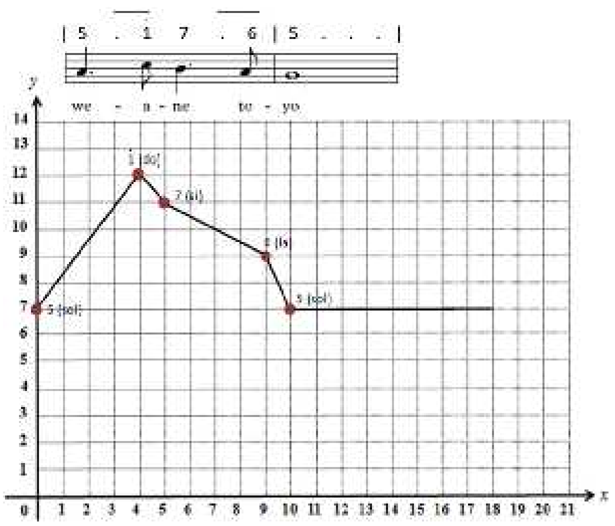


Figure 12. Example of Placement of Musical Notation in Cartesian Coordinates

In the above it can be seen that 5 (sol) lies at point (0,7), 1> (do) = (4, 12), 7 (si) = (5, 11), 6 (la) = (9, 9), 5 (sol) = (10, 7).

With the following conditions:

a. *y* axis represents the ratio of pitch distance and the *x axis* represents the beat duration.

b. The higher the pitch, the more the beam symbol will go up.

c. The distance ratio is arranged chromatically, so for example 1 = C then the distance between C and D, D with E, F with G, G with A, A with B is 2 while E with F and B with C is 1.

d. *x = 2* shift represents 1 tap
Do = C starting at point (0,0)

4. Relations and Functions

Consider the following three arrow diagrams.

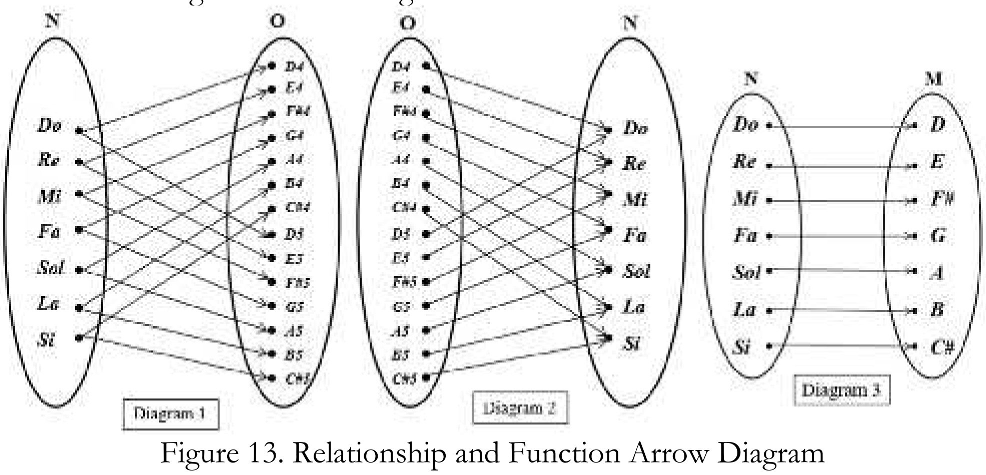


Figure 13. Relationship and Function Arrow Diagram

N = {set of notes}
M = {the collection of letter notes in the key of D Major}
O = {a collection of letter notes in D Major with different octave}

From the picture above, it can be concluded that there are relationships in music, but not all relations are mappings. For example the arrow diagram 1 is not a mapping, but only a relation, because there are domain members that have more than one partner in the codomain. A tone will have more than 1 pair of letter notes if you don't pay attention to the high-low position.

Meanwhile, if it is reversed, wherever the letter notation is located, it will have only one tone pair, as in the arrow diagram 2 which is a mapping, because each domain member only has at least one pair in the codomain. And the arrow diagram 3 is a one-to-one correspondence, that is, each domain has exactly one partner in the codomain, which is definitely a mapping, if the pitch matching pays attention to the high-low position.

5. Translation

In music there is the term diatonic scales. These seven-tone scales or modes are made up of different arrangements of whole and half steps and are called diatonic scales (Jones, 2007:23). Diatonic scales are divided into two, namely major and minor. The simplest scale and the basis for many other scales is C Major, which is composed of the notes C-D-E-F-G-A-B-C. Of the eight tones, the 1/2 tone (semi-tone) distance is located on the 3-4th and 7-8th (octave) notes, namely the notes E-F and B-C, while the others are 1 tone. The C major scale pattern can be seen in Figure 8.

In the research entitled "'TRIANGULAR' (Concept of Transformation of Geometry in Musical Composition)", Batara Sitohang explored by using points on Cartesian coordinates as representations of pitch points, in order to look for possible geometric transformation concepts as a reference for making musical compositions.

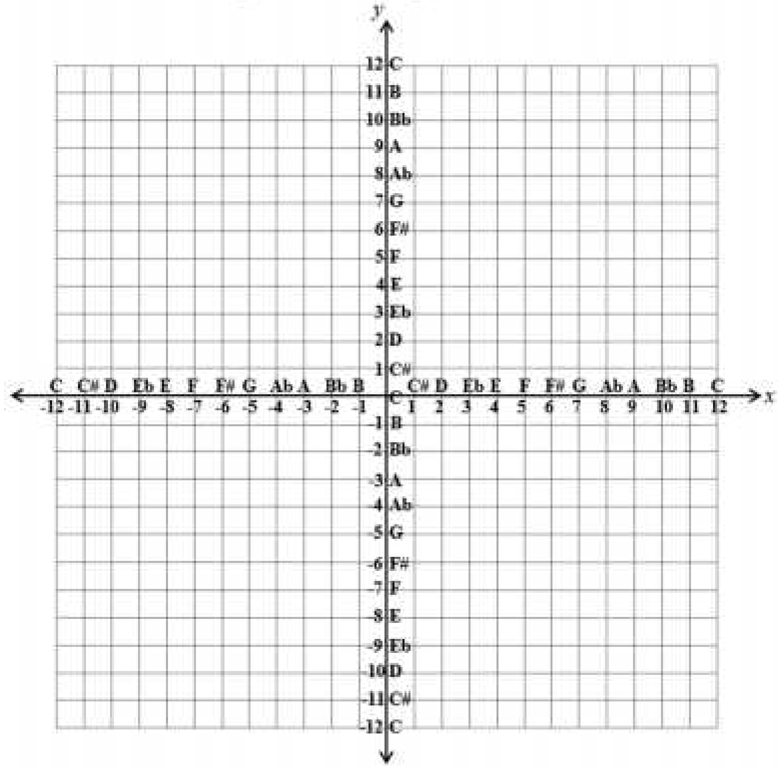


Figure 15. Tone Exploration in the Cartesian Coordinate Plane (Sitohang, 2018)

Sitohang uses the numbers 0 to 12 in the four quadrants of Cartesian coordinates, to represent the notes C to B arranged chromatically. The y-axis up and the x-axis to the right are ascending (from a lower tone to a higher one) while negative numbers are descending (from a higher tone to a lower one).

Based on this theory, the researcher looks for the possibility of a translational concept in the movement of scales by conducting experiments, namely placing several points according to the pattern of the C Major scale on Cartesian coordinates.

In Figure 9, if the pattern represented by the red dots is translated by $T = \binom{0}{2}$ it will produce shadow dots that represent the D Major scale, as shown in the following table.

Table 3. Results of Translation of the C Major Scale to D Major

Starting Point	C Major Scale	Shadow point	D major scale
(0,0)	C	(0,2)	D
(1,1)	D	(1,3)	E
(2,2)	E	(2,4)	F#
(3,2)	F	(3,4)	G
(4,3)	G	(4,5)	A
(5,4)	A	(5,6)	B
(6,5)	B	(6,7)	C#
(7,5)	C	(7,7)	D

In Figure 9 it can be seen that the initial pattern and the shadow are exactly the same, and it shows the point that corresponds to the tone matching. Then there is the concept of geometric transformation in the form of translation in the movement of scales.

CONCLUSION

Based on the results of the research that has been described, the following conclusions can be obtained: 1) ethnomathematics concepts in piano playing include; counting, locating, measuring, designing, explaining, playing, 2) implementation the results of ethnomathematics studies on piano playing in mathematics learning, that it; material for arithmetic operations on fractions, sets, Cartesian coordinates, relations and functions, as well as geometric transformations in the form of translations.

REFERENCE

Abdurrahman, Mulyono. 2009. *Education for Children with Learning Difficulties*. Jakarta: Rineka Cipta.

Barton, William David. "Ethnomathematics: Exploring Cultural Diversity in Mathematics"*, A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Mathematics Education 1996*. Auckland: The University of Auckland.

Bishop, AJ. 1997. *Mathematical Enculturation: A Cultural Perspective on Mathematics Education.* Kluwer Academic Publishers Group

Gazai, Rahmita Yuliana. "Meaningful Mathematics Learning" in the *Journal of Mathematics Education* Vol. 2, No. 3, 2016.

Gunawan, Francis Ivan. 2019. *Ethnomatematics Study and Analysis of Mathematical Fundamental Activities According to Bishop in the Bangka Belitung Cual Cloth Industry.* Yogyakarta: Unpublished Thesis Mathematics and Natural Science Education FKIP Sanata Dharma University.

Jones, Catherine Schmidt. 2007. *Understanding Basic Music Theory.* Texas: Connections.

Komariah, "Introducing Numbers to Early Childhood", in *Early Horizons: Vol. 4 No. 2,* November 2013

Rosa, Milton and Daniel Clark Orey. " Ethnomathemarics: The Cultural Aspect of Mathematics", in *Revista Latinoamericana de Etnomatematica,* vol.4, no. 2, 32-54, 2011.

Sitohang, Batara. 2018. *'TRIANGULAR' (Concept of Geometry Transformation in Musical Composition).* Yogyakarta: Unpublished Thesis Postgraduate Institute of the Arts of Indonesia.

Wijaya, Ariyadi. 2012. *Realistic Mathematics Education: An Alternative Approach to Learning Mathematics.* Yogyakarta: Science Graha.