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Title	ETHNOMATHEMATICS: PRANATAMANGSA SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA
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Dear Prof. Dr. Zulkardi, M.I.Komp., M.Sc.,
Editor in Chief of Journal on Mathematics Education

I hope this email finds you well.

I'm writing the manuscript entitled "Mathematical modeling of people of Yogyakarta" for consideration for publication in the Journal on Mathematics Education (JME). This manuscript was written using the format guidelines mentioned in the JME website.

This paper provides a comprehensive study on the mathematical modeling of people of Yogyakarta. As we know that mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics learning. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

This paper also describes my original work and is not under consideration by any other journal. I do not have any conflict of interest regarding this manuscript. This paper was reported as the research results I conducted as one of the requirements of our responsibility as a researcher in our university. This year, I didn't get funding for my research publication because of the COVID-19 Pandemic disease case in my country, so I would like to waive all article processing charges if my paper is accepted. Lastly, I do hope that this article can be published in this journal so that I can contribute my research results to your journal.

Thank you for receiving my manuscript and considering it for review. I do really appreciate your time and look forward to seeing your response.

Best Wishes,

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Title and Abstract

Title ETHNOMATHEMATICS: PRANATAMANGSA SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA

Abstract Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators are not yet aware of this richness in the learning process to integrate it as the starting point. It is hard to find in mathematics textbooks in Indonesia, which put cultural context as starting points. Therefore, this study aims to explore Yogyakarta's culture in terms of contexts used in mathematics learning. It is an ethnography study. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resource persons who understand the seasons, system, and calculation of birth and death days. It is to clarify the researcher's understanding of the literature. This study showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and funerary dates. These models have the potential to be used as a starting point in learning mathematics.

Indexing

Keywords mathematical modelling; ethnomodeling; Yogyakarta culture; seasons system; birth and death dates
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MATHEMATICAL MODELING OF PEOPLE OF YOGYAKARTA

Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics learning. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

Keywords: Mathematical modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but influenced by historical aspects, environment, social, and geography, or we call it a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in flat-not flexible ways and far from cultures as to how it developed (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So,

mathematics learning then becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoning, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning to make students love mathematics, get motivated and improve creativity in doing mathematics.

In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). In ethnomathematics, it is called the ethnomodelling approach, a way to student mathematical phenomenon in different cultural contexts (Rosa & Orey, 2013). In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring mathematical phenomenon around students' around the hood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This is an opportunity in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called '*pranatamangsa*.' Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to head seaward for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which have in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to

study Yogyakarta's culture in mathematical modeling, which can be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture has mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

This is an ethnography that studies describing the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. Therefore, this study observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. Calculating season systems in Yogyakarta is to predict how much fish will be caught and tools for fishing and farmers to determine what types of crops they will plan and crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017).

Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishers to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa*

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.

2. *Mangsa Karo*

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

3. *Mangsa Katelu*

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

4. *Mangsa Kapat*

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.

5. *Mangsa Kalima*

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.

6. *Mangsa Kanem*

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea

conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. Mangsa Kapitu

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. Mangsa Kawolu

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. Mangsa Kasanga

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. Mangsa Kasepuluh

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. Mangsa Dhesta

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha*

    It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishers, this *pranatamangsa* plays essential roles in their lives to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 1.

Table 1. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				*Mangsa*
		Month	Value	Calculation		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 1 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6
2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1.

Figure 1. Wheel of *Pramanamangsa*

Figure 1 depicts *pranatamangsa* as a primary reference for farmers and fishers, it included the formulas to determine the seasons and its units. Its goal is to be a reference for students and teachers in Yogyakarta.

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in days 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the excellent days for organizing it and Memoriam date of praying for the death (Pariyem, 2017).

1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make Memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo 5. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo 5 specifies the sacred day (Robiyanto & Puryandani, 2015).

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. This year is divisible by 4, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 2.

Table 2. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = Today - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = today

N = Year-n

s = Year today

q = Additional day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 3, it concludes that:

Additional day	=	Days in a year (mod 5)
Sacred day in year-n	=	Today's sacred day - [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

$$p = t \pmod 5$$

$$PN = u - [\{n\text{-}s) - p\} + (k + 1)] \bmod 5$$

Information:

PN	=	Sacred day in year-n
u	=	Today's sacred day
n	=	Year-n
s	=	Year today
p	=	Additional day
k	=	Number of leap years
t	=	Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5)
= 365 (mod 5)
= 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days

= Legi

Therefore, from the calculations, it concludes that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

a. Mathematical modeling on date of death ceremonial

On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 4.

Table 4. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H	=	Date of death ceremonial
a	=	Additional days
b	=	Mourn day in n by n = 3, 7, 40, 100, and 1000
C	=	Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 5.

Table 5. Model for calculating the sacred day of the death

The mourn day	**The value of the sacred day**	**Value of the day**	**Number of Increased *Pasaran* Days**
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional days for the sacred day = The Mourn day (mod 5) -1

The ceremonial sacred day = Dead day + additional sacred day

or it can be written as:

$$D = b \pmod 7 - 1$$

$$P = c + d$$

Information:

P	=	The sacred day of the death in year-n
d	=	Number of additional sacred days
b	=	The-n mourn day n = 3, 7, 40, 100, and 1000
c	=	The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 6.

Table 6. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 7.

Table 7. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 8.

Table 8. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture have added references and knowledge concerning the use of cultural contexts as starting points in learning mathematics. For instance, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. It has been studied about teaching statistics by using the kemaro island legend (Lestariningsih, Putri, &

Darmawijoyo, 2012). On the other hand, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019).

The low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study is affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This implies to students who memorize formulas without knowing its meaning and being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

In Yogyakarta's culture, it has some mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishers. They predict which fish they will catch and tools to be used by studying the natural phenomenon. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo five and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. A comprehensive study of this Yogyakarta's culture is to find mathematical modeling to be used as a starting point in mathematics learning in Yogyakarta to improve their understanding, especially for those who live in villages.

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17 of 27

[JME] Editor Decision Inbox

Prof. Dr. Cyril Julie <ejournal@unsri.ac.id> — Thu, Jul 30, 2020, 10:53 AM
to me, Wahid

Dear Rully Charitas Indra Prahmana,

It is my great pleasure to inform you that your paper entitled "Mathematical Modeling of People of Yogyakarta" has been ACCEPTED with REVISION and will be published in the Journal on Mathematics Education (JME). Your paper will be published for forthcoming issues after suitable revision and fulfill the JME's standard.

Congratulations!

Authors are encouraged to carefully consider the reviewers' comments and suggestions for improvement of your manuscript, such as:

Reviewer A:
The paper is an interesting and relevant contribution to mathematics education research. However, also some issues need to be resolved. My main comments are included in the document. In summary, it would be helpful when the author(s) add a research question, extend the method section with information about the selection of participants and methods of analysis. The results section needs to be written as a report of results.

Reviewer B:
The title, method, and results need to confirm because there are many claims of the writer and did not describe data.

Reviewer C:
The article is very interesting, however, it is recommended that the authors develop further the problem of the study as well as explain the cultural aspects of modeling they are using in this study. It is also recommended that the authors detail the methodological procedures in order to explain how data were analyzed and how the results were interpreted. It is necessary that the authors also develop discussions of the results as well as connect their work to other research done in this area in their conclusion.

Reviewer D:
This was a joy to read... a complete and total joy. I congratulate the authors. The article is excellent ... well written and clear, it will be a great addition to the field. The publishers should accept it, and the author congratulated them. I look forward to seeing it in print very soon. The circle graph might be more beneficial if translated into English, but it is good in the language as seen as well. So sorry... I am delayed here because of this code thing, and I have the end of semester responsibilities and this is taking far too long for you, my apologies. Beautiful article, well written.

Reviewer E:
Revision Mayor with many parts in the article need to describe novelty from this research

Reviewer F:
The word 'pranatamangsa.' should appear in the title and some reference to it should be in the abstract. This calendrical system is fundamental in this research.

Reviewer G:
The author should consider the title of this paper, especially for using "People".

Reviewer H:
The representation of English writing should be improved

Reviewer I:
Please clarify the definition of mathematical modeling and ethnomodeling in this study. How did you ensure the validity and reliability of this study? Other comments are embedded in the paper.

For more details, please check the reviewers' comment file in your account. Furthermore, the author must make sure all references have DOI and follow this guideline to ensure that your final file is complete and in the correct format (https://bit.ly/33GvXT3) for preparing their paper strictly. You can follow the paper that already published in JME. The manuscript should also have been carefully revised and similarity check no more than 20%.

Please submit the final revised paper along with the Copyright Transfer Agreement, recapitulation the contents of the revised article, and similarity check result file to the email: jme@unsri.ac.id or via your JME OJS Account as an Author Version. The revised manuscript should be submitted by August 7, 2020; if you anticipate that you will be unable to meet this deadline, please notify the Editorial Office. Should you have any questions, please do not hesitate to contact us.

Thank you very much for your cooperation. I do really appreciate it.

Kind regards,

Prof. Dr. Cyril Julie
(SCOPUS ID: 9434368700), University of the Western Cape, School of Science and Mathematics Education, Bellville

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IMPORTANT:
"Please revise and give a comment in the attached file and it is not permitted to send a new file, other than the revised results of the attached file"

Hasil review dari 9 reviewer dengan 5 diantaranya memberikan catatan pada artikel nya secara langsung, yaitu Reviewer A, B, E, H, dan I

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MATHEMATICAL MODELING OF PEOPLE OF YOGYAKARTA

Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the special Region of Yogyakarta (DIY). Yogyakarta is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics education. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential starting points for learning mathematics.

Keywords: Mathematical modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

How to Cite: (2020). Mathematical modeling of people of Yogyakarta. *Journal on Mathematics Education, 11*(3), xx-xx.

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but is influenced by historical aspects, environment, social, and geography, or we call it a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in flat, and not flexible ways and far from cultures in which it developed and is taught (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016).

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So, mathematics learning then becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoners, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning aims to make students love mathematics, get motivated and improve creativity in doing mathematics.

In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). In ethnomathematics, the ethnomodelling approach is a way to study a mathematical phenomenon in different cultural contexts (Rosa & Orey, 2013). In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring mathematical phenomenon around students' neighborhood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques. This creates opportunities in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in the students' culture. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called '*pranatamangsa*.' Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to head seaward for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which exist in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to

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study Yogyakarta's culture in mathematical modeling, which has the potential to be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected and analyzed. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture includes mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

This is an ethnography that studies describing the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography: languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. Therefore, this study observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. to the calculation predicts how much fish will be caught and tools for fishing and farmers, and to determine what types of crops they have to plan and the crop dates. It is also found that mathematical modeling is used in determining dates for birth-death ceremonials.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017).

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Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishers to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa*

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.
2. *Mangsa Karo*

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
3. *Mangsa Katelu*

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
4. *Mangsa Kapat*

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.
5. *Mangsa Kalima*

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.
6. *Mangsa Kanem*

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea

conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. Mangsa Kapitu
   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.
8. Mangsa Kawolu
   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.
9. Mangsa Kasanga
   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.
10. Mangsa Kasepuluh
   It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.
11. Mangsa Dhesta
   It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.
12. *Mangsa Sadha*
   It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishers, this *pranatamangsa* plays essential roles in their lives to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 1.

Table 1. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				*Mangsa*
		Month	Value	Calculation		
1	January-June	January	1	+ 6	1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4		4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
2	July-December	July	7	- 6	7-6 = 1	*Mangsa Kasa*
		August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10		10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 1 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1.

Figure 1. Wheel of *Pramanamangsa*

Figure 1 depicts *pranatamangsa* as a primary reference for farmers and fishers, it included the formulas to determine the seasons and its units. Its goal is to be a reference for students and teachers in Yogyakarta.

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in days 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the excellent days for organizing it and Memoriam date of praying for the death (Pariyem, 2017).

1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make Memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo five. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo five specifies the sacred day (Robiyanto & Puryandani, 2015).

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Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. Such years are divisible by four. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 2.

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Table 2. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = Today - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = today

N = Year-n

s = Year today

q = Additional day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 3, it concludes that:

Additional day	=	Days in a year (mod 5)
Sacred day in year-n	=	Today's sacred day - [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN	=	Sacred day in year-n
u	=	Today's sacred day
n	=	Year-n
s	=	Year today
p	=	Additional day
k	=	Number of leap years
t	=	Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5)
= 365 (mod 5)
= 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5

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= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days

= Legi

Therefore, from the calculations, it can be concluded that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

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2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

a. Mathematical modeling on date of death ceremonial

On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 4.

Table 4. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H = Date of death ceremonial

a = Additional days

b = Mourn day in n by n = 3, 7, 40, 100, and 1000

C = Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 5.

Table 5. Model for calculating the sacred day of the death

The mourn day	**The value of the sacred day**	**Value of the day**	**Number of Increased *Pasaran* Days**
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional days for the sacred day = The Mourn day (mod 5) -1

The ceremonial sacred day = Dead day + additional sacred day

or it can be written as:

$$D = b \pmod{7} - 1$$

$$P = c + d$$

Information:

P = The sacred day of the death in year-n

d = Number of additional sacred days

b = The-n mourn day n = 3, 7, 40, 100, and 1000

c = The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 6.

Table 6. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 7.

Table 7. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 8.

Table 8. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture have added references and knowledge concerning the use of cultural contexts as starting points in learning mathematics. For instance, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. The kemaro island legend can be used to teach statistics (Lestariningsih, Putri, & Darmawijoyo, 2012). In addition,

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several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019).

The low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study is affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written in the textbooks without igniting interactive dialogue to enhance students' critical reasoning and to communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This implies to students who memorize formulas without knowing its meaning and being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-cultural contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

Yogyakarta's culture includes mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishers. They predict which fish they will catch and tools to be used by studying natural phenomena. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo five and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. A comprehensive study of this Yogyakarta's culture is to find mathematical modeling to be used as a starting point in mathematics learning in Yogyakarta to improve their understanding, especially for those who live in villages.

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ACKNOWLEDGMENTS

The researcher wishes to thank to Mr. Gasiman, Mr. Salmet Riyadi, Granny Sumirah, and Granny Pariyem from Kulon Progo district who have helped this study. I also would like to thank to Irma Risdiyanti who has helped collecting data and making illustration. Last but not least, I would like to thank to Universitas Ahmad Dahlan which has supported me in doing this research and publication.

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MATHEMATICAL MODELING OF PEOPLE OF YOGYAKARTA

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Abstract
Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics learning. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

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Keywords: Mathematical modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak
Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

How to Cite: (2020). Mathematical modeling of people of Yogyakarta. *Journal on Mathematics Education, 11*(3), xx-xx.

Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but influenced by historical aspects, environment, social, and geography, or we call it a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in flat-not flexible ways and far from cultures as to how it developed (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So,

mathematics learning then becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoning, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning to make students love mathematics, get motivated and improve creativity in doing mathematics.

In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). In ethnomathematics, it is called the ethnomodelling approach, a way to student mathematical phenomenon in different cultural contexts (Rosa & Orey, 2013). In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring mathematical phenomenon around students' around the hood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

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Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This is an opportunity in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called '*pranatamangsa*.' Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to head seaward for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which have in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to

study Yogyakarta's culture in mathematical modeling, which can be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture has mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

This is an ethnography that studies describing the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. Therefore, this study observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. Calculating season systems in Yogyakarta is to predict how much fish will be caught and tools for fishing and farmers to determine what types of crops they will plan and crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017).

Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishers to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa*

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.

2. *Mangsa Karo*

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

3. *Mangsa Katelu*

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

4. *Mangsa Kapat*

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.

5. *Mangsa Kalima*

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.

6. *Mangsa Kanem*

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea

conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. Mangsa Kapitu

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. Mangsa Kawolu

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. Mangsa Kasanga

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. Mangsa Kasepuluh

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. Mangsa Dhesta

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha*

    It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishers, this *pranatamangsa* plays essential roles in their lives to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 1.

Table 1. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				*Mangsa*
		Month	Value	Calculation		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 1 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1.

Figure 1. Wheel of *Pramanamangsa*

Figure 1 depicts *pranatamangsa* as a primary reference for farmers and fishers, it included the formulas to determine the seasons and its units. Its goal is to be a reference for students and teachers in Yogyakarta.

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in days 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the excellent days for organizing it and Memoriam date of praying for the death (Pariyem, 2017).

1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make Memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo 5. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo 5 specifies the sacred day (Robiyanto & Puryandani, 2015).

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. This year is divisible by 4, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 2.

Table 2. Calculating the additional day

Days in a year	Additional day
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = Today - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = today

N = Year-n

s = Year today

q = Additional day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 3.

Table 3. Calculating the additional day

Days in a year	Additional day
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 3, it concludes that:

Additional day	=	Days in a year (mod 5)
Sacred day in year-n	=	Today's sacred day - [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN	=	Sacred day in year-n
u	=	Today's sacred day
n	=	Year-n
s	=	Year today
p	=	Additional day
k	=	Number of leap years
t	=	Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5)
= 365 (mod 5)
= 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days

= Legi

Therefore, from the calculations, it concludes that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

a. Mathematical modeling on date of death ceremonial

On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 4.

Table 4. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H	=	Date of death ceremonial
a	=	Additional days
b	=	Mourn day in n by n = 3, 7, 40, 100, and 1000
C	=	Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 5.

Table 5. Model for calculating the sacred day of the death

The mourn day	**The value of the sacred day**	**Value of the day**	**Number of Increased *Pasaran* Days**
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional days for the sacred day = The Mourn day (mod 5) -1

The ceremonial sacred day = Dead day + additional sacred day

or it can be written as:

$$D = b \pmod 7 - 1$$

$$P = c + d$$

Information:

P	=	The sacred day of the death in year-n
d	=	Number of additional sacred days
b	=	The-n mourn day n = 3, 7, 40, 100, and 1000
c	=	The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 6.

Table 6. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 7.

Table 7. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 8.

Table 8. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture have added references and knowledge concerning the use of cultural contexts as starting points in learning mathematics. For instance, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. It has been studied about teaching statistics by using the kemaro island legend (Lestariningsih, Putri, &

Darmawijoyo, 2012). On the other hand, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019).

The low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study is affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This implies to students who memorize formulas without knowing its meaning and being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

In Yogyakarta's culture, it has some mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishers. They predict which fish they will catch and tools to be used by studying the natural phenomenon. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo five and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. A comprehensive study of this Yogyakarta's culture is to find mathematical modeling to be used as a starting point in mathematics learning in Yogyakarta to improve their understanding, especially for those who live in villages.

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MATHEMATICAL MODELING OF PEOPLE OF YOGYAKARTA

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Abstract
Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics learning. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

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Keywords: Mathematical modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak
Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but influenced by historical aspects, environment, social, and geography, or we call it a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in flat-not flexible ways and far from cultures as to how it developed (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So,

mathematics learning then becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoning, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning to make students love mathematics, get motivated and improve creativity in doing mathematics.

In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). In ethnomathematics, it is called the ethnomodelling approach, a way to student mathematical phenomenon in different cultural contexts (Rosa & Orey, 2013). In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring mathematical phenomenon around students' around the hood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This is an opportunity in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called '*pranatamangsa*.' Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to head seaward for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which have in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to

study Yogyakarta's culture in mathematical modeling, which can be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture has mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

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METHOD

This is an ethnography that studies describing the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. Therefore, this study observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta.

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RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. Calculating season systems in Yogyakarta is to predict how much fish will be caught and tools for fishing and farmers to determine what types of crops they will plan and crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017).

Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishers to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa*

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.
2. *Mangsa Karo*

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
3. *Mangsa Katelu*

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
4. *Mangsa Kapat*

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.
5. *Mangsa Kalima*

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.
6. *Mangsa Kanem*

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea

conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. Mangsa Kapitu

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. Mangsa Kawolu

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. Mangsa Kasanga

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. Mangsa Kasepuluh

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. Mangsa Dhesta

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha*

    It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

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For Javanese people who work as farmers and fishers, this *pranatamangsa* plays essential roles in their lives to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 1.

Table 1. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				*Mangsa*
		Month	Value	Calculation		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 1 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1.

Figure 1. Wheel of *Pramanamangsa*

Figure 1 depicts *pranatamangsa* as a primary reference for farmers and fishers, it included the formulas to determine the seasons and its units. Its goal is to be a reference for students and teachers in Yogyakarta.

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in days 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the excellent days for organizing it and Memoriam date of praying for the death (Pariyem, 2017).

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1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make Memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo 5. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo 5 specifies the sacred day (Robiyanto & Puryandani, 2015).

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. This year is divisible by 4, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 2.

Table 2. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = Today - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n
m = today
N = Year-n
s = Year today
q = Additional day
k = Number of leap years
t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 5) = 0 means +5

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Based on the explanation from the mathematical modeling in Table 3, it concludes that:

Additional day	=	Days in a year (mod 5)
Sacred day in year-n	=	Today's sacred day - [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN	=	Sacred day in year-n
u	=	Today's sacred day
n	=	Year-n
s	=	Year today
p	=	Additional day
k	=	Number of leap years
t	=	Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5)
= 365 (mod 5)
= 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days

= Legi

Therefore, from the calculations, it concludes that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

a. Mathematical modeling on date of death ceremonial

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On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 4.

Table 4. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H	=	Date of death ceremonial
a	=	Additional days
b	=	Mourn day in n by n = 3, 7, 40, 100, and 1000
C	=	Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 5.

Table 5. Model for calculating the sacred day of the death

The mourn day	**The value of the sacred day**	**Value of the day**	**Number of Increased *Pasaran* Days**
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional days for the sacred day	=	The Mourn day (mod 5) -1
The ceremonial sacred day	=	Dead day + additional sacred day

or it can be written as:

$$D = b \pmod 7 - 1$$

$$P = c + d$$

Information:

P	=	The sacred day of the death in year-n
d	=	Number of additional sacred days
b	=	The-n mourn day n = 3, 7, 40, 100, and 1000
c	=	The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 6.

Table 6. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 7.

Table 7. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 8.

Table 8. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture have added references and knowledge concerning the use of cultural contexts as starting points in learning mathematics. For instance, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. It has been studied about teaching statistics by using the kemaro island legend (Lestariningsih, Putri, &

Darmawijoyo, 2012). On the other hand, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019).

The low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study is affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This implies to students who memorize formulas without knowing its meaning and being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

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CONCLUSION

In Yogyakarta's culture, it has some mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishers. They predict which fish they will catch and tools to be used by studying the natural phenomenon. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo five and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. A comprehensive study of this Yogyakarta's culture is to find mathematical modeling to be used as a starting point in mathematics learning in Yogyakarta to improve their understanding, especially for those who live in villages.

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MATHEMATICAL MODELING OF PEOPLE OF YOGYAKARTA

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Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics learning. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

Keywords: Mathematical modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but influenced by historical aspects, environment, social, and geography, or we call it a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in flat-not flexible ways and far from cultures as to how it developed (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So,

mathematics learning then becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoning, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning to make students love mathematics, get motivated and improve creativity in doing mathematics.

In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). In ethnomathematics, it is called the ethnomodelling approach, a way to student mathematical phenomenon in different cultural contexts (Rosa & Orey, 2013). In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring mathematical phenomenon around students' around the hood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

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Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This is an opportunity in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called '*pranatamangsa*.' Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to head seaward for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which have in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to

study Yogyakarta's culture in mathematical modeling, which can be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture has mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

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METHOD

This is an ethnography that studies describing the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. Therefore, this study observes and describes the system of knowledge of Yogyakarta's culture.

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In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta.

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RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. Calculating season systems in Yogyakarta is to predict how much fish will be caught and tools for fishing and farmers to determine what types of crops they will plan and crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

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Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017).

Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishers to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa*
   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.
2. *Mangsa Karo*
   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
3. *Mangsa Katelu*
   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
4. *Mangsa Kapat*
   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.
5. *Mangsa Kalima*
   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.
6. *Mangsa Kanem*
   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea

conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. Mangsa Kapitu

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. Mangsa Kawolu

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. Mangsa Kasanga

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. Mangsa Kasepuluh

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. Mangsa Dhesta

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha*

    It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishers, this *pranatamangsa* plays essential roles in their lives to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 1.

Table 1. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				*Mangsa*
		Month	Value	Calculation		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 1 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1.

Figure 1. Wheel of *Pramanamangsa*

Figure 1 depicts *pranatamangsa* as a primary reference for farmers and fishers, it included the formulas to determine the seasons and its units. Its goal is to be a reference for students and teachers in Yogyakarta.

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in days 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the excellent days for organizing it and Memoriam date of praying for the death (Pariyem, 2017).

1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make Memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo 5. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo 5 specifies the sacred day (Robiyanto & Puryandani, 2015).

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. This year is divisible by 4, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 2.

Table 2. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = Today - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = today

N = Year-n

s = Year today

q = Additional day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 3, it concludes that:

Additional day	=	Days in a year (mod 5)
Sacred day in year-n	=	Today's sacred day - [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN	=	Sacred day in year-n
u	=	Today's sacred day
n	=	Year-n
s	=	Year today
p	=	Additional day
k	=	Number of leap years
t	=	Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5)
= 365 (mod 5)
= 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days

= Legi

Therefore, from the calculations, it concludes that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

a. Mathematical modeling on date of death ceremonial

On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 4.

Table 4. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H	=	Date of death ceremonial
a	=	Additional days
b	=	Mourn day in n by n = 3, 7, 40, 100, and 1000
C	=	Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 5.

Table 5. Model for calculating the sacred day of the death

The mourn day	The value of the sacred day	Value of the day	Number of Increased *Pasaran* Days
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional days for the sacred day = The Mourn day (mod 5) -1

The ceremonial sacred day = Dead day + additional sacred day

or it can be written as:

$$D = b \pmod 7 - 1$$

$$P = c + d$$

Information:

P	=	The sacred day of the death in year-n
d	=	Number of additional sacred days
b	=	The-n mourn day n = 3, 7, 40, 100, and 1000
c	=	The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 6.

Table 6. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 7.

Table 7. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 8.

Table 8. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture have added references and knowledge concerning the use of cultural contexts as starting points in learning mathematics. For instance, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. It has been studied about teaching statistics by using the kemaro island legend (Lestariningsih, Putri, &

Darmawijoyo, 2012). On the other hand, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019).

The low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study is affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This implies to students who memorize formulas without knowing its meaning and being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

In Yogyakarta's culture, it has some mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishers. They predict which fish they will catch and tools to be used by studying the natural phenomenon. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo five and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. A comprehensive study of this Yogyakarta's culture is to find mathematical modeling to be used as a starting point in mathematics learning in Yogyakarta to improve their understanding, especially for those who live in villages.

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MATHEMATICAL MODELING OF PEOPLE OF YOGYAKARTA

Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of this richness in the learning process to integrate it as the starting point. Therefore, this study aimed at exploring Yogyakarta's culture in terms of contexts that can be used in mathematics learning. This is an ethnography study with ethnomodeling. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

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Keywords: Mathematical modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but influenced by historical aspects, environment, social, and geography, or we call it a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in flat-not flexible ways and far from cultures as to how it developed (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So,

mathematics learning then becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoning, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning to make students love mathematics, get motivated and improve creativity in doing mathematics.

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In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). In ethnomathematics, it is called the ethnomodelling approach, a way to student mathematical phenomenon in different cultural contexts (Rosa & Orey, 2013). In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring mathematical phenomenon around students' around the hood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

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Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This is an opportunity in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called '*pranatamangsa*.' Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to head seaward for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which have in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to

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Commented [P6]: Literature or culture?

study Yogyakarta's culture in mathematical modeling, which can be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture has mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

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METHOD

Commented [P8]: how did you ensure the validity and reliability of this study?

This is an ethnography that studies describing the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. Therefore, this study observes and describes the system of knowledge of Yogyakarta's culture.

Commented [P9]: Cultural community?

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta.

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RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. Calculating season systems in Yogyakarta is to predict how much fish will be caught and tools for fishing and farmers to determine what types of crops they will plan and crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

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Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017).

Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishers to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa*

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.

2. *Mangsa Karo*

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

3. *Mangsa Katelu*

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

4. *Mangsa Kapat*

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.

5. *Mangsa Kalima*

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.

6. *Mangsa Kanem*

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea

conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. Mangsa Kapitu

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. Mangsa Kawolu

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. Mangsa Kasanga

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. Mangsa Kasepuluh

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. Mangsa Dhesta

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha*

    It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishers, this *pranatamangsa* plays essential roles in their lives to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 1.

Commented [P12]: Please consider breaking down into two sentences for the clarity of the meaning.

Table 1. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				*Mangsa*
		Month	Value		Calculation	
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 1 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1.

Figure 1. Wheel of *Pramanamangsa*

Figure 1 depicts *pranatamangsa* as a primary reference for farmers and fishers, it included the formulas to determine the seasons and its units. Its goal is to be a reference for students and teachers in Yogyakarta.

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in days 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the excellent days for organizing it and Memoriam date of praying for the death (Pariyem, 2017).

Commented [P13]: For the death

Commented [P14]: The meaning is unclear

1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make Memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo 5. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo 5 specifies the sacred day (Robiyanto & Puryandani, 2015).

Commented [P15]: Please consider paraphrasing for clarity

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. This year is divisible by 4, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 2.

Table 2. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Commented [P16]: This could be deleted

Additional day = Days in a year (mod 7)

Day on year-n = Today - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n
m = today
N = Year-n
s = Year today
q = Additional day
k = Number of leap years
t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 3, it concludes that:

Commented [P17]: This could be deleted

Additional day = Days in a year (mod 5)

Sacred day in year-n = Today's sacred day - [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

$$p = t \pmod 5$$

$$PN = u - [\{n\text{-}s) - p\} + (k + 1)] \bmod 5$$

Information:

PN = Sacred day in year-n

u = Today's sacred day

n = Year-n

s = Year today

p = Additional day

k = Number of leap years

t = Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

$$\begin{aligned} Q &= t \pmod 7 \\ &= 365 \pmod 7 \\ &= 1 \end{aligned}$$

$$\begin{aligned} HN &= m - [\{n\text{-}s) \times q\} + k] \bmod 7 \\ &= \text{Thursday} - [\{(2017\text{-}1945) \times 1\} + 18] \bmod 7 \\ &= \text{Thursday} - [\{72 \times 1\} + 18] \bmod 7 \\ &= \text{Thursday} - [72 + 18] \bmod 7 \\ &= \text{Thursday} - [90] \bmod 7 \\ &= \text{Thursday} - 6 \text{ days} \\ &= \text{Friday} \end{aligned}$$

Meanwhile, his/her sacred day is:

$$\begin{aligned} P &= t \pmod 5 \\ &= 365 \pmod 5 \\ &= 0 \end{aligned}$$

$$\begin{aligned} PN &= u - [\{(n\text{-}s) \times p\} + k] \bmod 5 \\ &= \text{Wage} - [\{(2017\text{-}1945) \times 0\} + 18] \bmod 5 \end{aligned}$$

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days

= Legi

Therefore, from the calculations, it concludes that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

Commented [P18]: Is there any other expression which is more polite?

Commented [P19]: Maybe you could consider a more polite way, such as passed away (for the entire paper).

a. Mathematical modeling on date of death ceremonial

On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 4.

Commented [P20]: remainder

Table 4. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H = Date of death ceremonial

a = Additional days

b = Mourn day in n by n = 3, 7, 40, 100, and 1000

C = Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 5.

Commented [P21]: remainder

Table 5. Model for calculating the sacred day of the death

The mourn day	The value of the sacred day	Value of the day	Number of Increased *Pasaran* Days
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional days for the sacred day = The Mourn day (mod 5) -1

The ceremonial sacred day = Dead day + additional sacred day

or it can be written as:

$$D = b \pmod 7 - 1$$

$$P = c + d$$

Information:

P = The sacred day of the death in year-n

d = Number of additional sacred days

b = The-n mourn day n = 3, 7, 40, 100, and 1000

c = The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 6.

Table 6. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 7.

Table 7. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 8.

Table 8. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture have added references and knowledge concerning the use of cultural contexts as starting points in learning mathematics. For instance, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. It has been studied about teaching statistics by using the kemaro island legend (Lestariningsih, Putri, &

Darmawijoyo, 2012). On the other hand, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019).

The low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study is affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This implies to students who memorize formulas without knowing its meaning and being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

In Yogyakarta's culture, it has some mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishers. They predict which fish they will catch and tools to be used by studying the natural phenomenon. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo five and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. A comprehensive study of this Yogyakarta's culture is to find mathematical modeling to be used as a starting point in mathematics learning in Yogyakarta to improve their understanding, especially for those who live in villages.

Commented [P22]: I think the term 'mathematical modeling' has not been defined in this paper. As far as I concern, modeling is a process emerging from the contextual situation to a more formal mathematics. Thus, it is difficult to understand this sentence which state that "a culture has some mathematical modeling".

Commented [P23]: please consider paraphrasing

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ETHNOMATHEMATICS: *PRANATAMANGSA* SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA

Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their problems and or environments. Along with its development, mathematics has been taught through formal education or schooling in the routine not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of culture richness in the learning process to integrate it as the starting point. Hardly to be found in mathematics textbooks in Indonesia which put cultural context as starting points. Therefore, this study aimed to explore Yogyakarta's culture in terms of contexts that can be used in mathematics education. This is an ethnography study. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources resource persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

Keywords: Mathematical Modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but is influenced by historical aspects, environment, social, and geography, or we refer it as a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018). However, mathematics becomes formal mathematics when it comes to formal education or schooling in routine-not flexible ways and far from cultures in which it developed and is taught(Alangui, 2010;

Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So, mathematics learning becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoners, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning aims to make students love mathematics, get motivated and improve creativity in doing mathematics.

There are several ways to integrate ethnomathematics in teaching and learning (Rosa & Orey, 2017). One of the approaches is ethno-modeling which was firstly introduced by Bessanezi (2002). In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). Rosa and Orey (2013) stated that ethnomodelling would allow us to see mathematics performed holistically. In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring phenomenon around students' neighbourhood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This creates opportunities in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in students' culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called *pranatamangsa*. Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to sail for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which existin several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to study Yogyakarta's culture in mathematical modeling, which has the potential to be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture includes mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

The method used in this research is an ethnographic method, which is a method that describes the culture of a community (Spardley & McCurdy, 1989). Ethnography was chosen as the method in this study because it is in line with the aims of ethnomathematics which study ideas, methods, and techniques in a particular culture from the original view of members of that culture (Asher & D'Ambrosio, 1994; Shirley & Palhares, 2016). Ethnographic methods involve learning about cultures that see, hear, speak, and act in different ways and in ways that they find themselves (Spradley & McCurdy, 1989). Data collection was carried out by field studies and interviews with Mr. Riyadi and Mr. Gasiman, farmers and fishermen on the coast of Bugel, Panjatan, Kulon Progo to know, explore and clarify comprehensively about one of the bases for catching fish at sea such as predicting catch fish, tools, weather conditions, and risks, as well as a basis to farm in the fields, predict the kind of plant will be planted and predict the times when planting, harvesting and others.

In this study, uses three boundaries of the coverage area are used which are the basis for determining the research subject, that are community unity consisting of education that speaks one language or accent in the same language, community unity which is limited by the boundaries of an administrative political area and community unity which experiences one experience. the same history, as the limits that have been set in ethnographic research to show the authenticity of culture under study, there is no mixture with other cultures (Clifton. 0000; Koentjaradiningrat, 2016). Therefore, it was determined that the community unit to be studied was the original Yogyakarta people who used the same accent, that are the Javanese language, limited by the same administrative area, namely the Special Region of Yogyakarta and experienced the same historical experience, that is history when living, growing and developing in Yogyakarta.

Koentjaradiningrat (2016) explains that in ethnographic research there were seven main descriptions produced by ethnographers, that is language, technology systems, economic systems, social organizations, knowledge systems, arts, and religion. In this study, the researcher will focus on one main description, that is the knowledge system because, to dissect the techniques used by the community in making batik motifs, the researcher must observe and dive into the knowledge and technology systems to find the knowledge base used in the process catching fish and farming activities. Even so, it does not rule out that other cultural elements will also be studied because they are related to one another.

In conducting ethnomathematic exploration, researchers begin with four general questions that are the essence of ethnographic principles, that is “where to start looking?”, “how to look?”, “how to recognize that you have found something significant?”, “how to understand what it is?”. The results of data collection were collected in the form of pictures, videos, and field notes, then were analyzed to see the relationship between the mathematical knowledge system and culture and to see the mathematical conceptions that exist in the catching fish and farming activity. Then the findings are described in the results of this study. Based on these four general questions, the research stages are organized in Table 1.

Table 1. Design of Ethnography Research

General Questions	Initial Answers	Starting Point	Specific Activity
Where to start looking?	In the activities of catching fish and farming carried out by the people of Yogyakarta where there are mathematical practices in it.	Culture	Conducting interviews with people who have knowledge of Javanese culture in the Yogyakata community or those who catching fish and farming.
How to look?	Investigating aspects of catching fish and farmingof the people of Yogyakarta related to mathematics practice.	Alternative thinking, technology and knowledge system	Determine what ideas are contained in catching fish and farming activities of the people of Yogyakarta related to mathematics practice.
What it is?	Evidence (Results of alternative thinking in the previous process)	Philosophy of mathematics	Identifying characteristics in the activity of catching fish and farming Yogyakarta society related to mathematics practice. It shows that the activity of catching fish and farming activities for the people of Yogyakarta does have a mathematical character seen from the elements of knowledge and art systems used in everyday life.
What it means?	Valued important for culture and important	Anthropologist	Describes the relationship between the two systems of

	value patterns for mathematics		mathematical knowledge and culture. Describe mathematical conceptions that exist in the activity of catching fish and farming for the people of Yogyakarta.

This is an ethnography that studies description of the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. This study only observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta. These respondents were purposively selected to gain more information based on their experiences. The interviews were conducted with semi-structured interview. The data from interviews were analyzed through content analysis to find the general ideas of pranatamangsa being used and helpful for them. The data from the documents were analyzed through content analysis and showed useful diagram depicting seasons division.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. to the calculation predict how much fish, types of fish will be caught and tools for fishing and farmers, and determine what types of crops they have to plan and the crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017). Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishermen to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa* (First season)

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.

2. *Mangsa Karo* (Second season)

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

3. *Mangsa Katelu* (Third season)

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.

4. *Mangsa Kapat* (Fourth season)

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.

5. *Mangsa Kalima* (Fifth season)

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.

6. *Mangsa Kanem* (Sixth season)

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. *Mangsa Kapitu* (Seventh season)

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. *Mangsa Kawolu* (Eighth season)

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. *Mangsa Kasanga* (Ninth season)

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. *Mangsa Kasepuluh* (Tenth season)

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. *Mangsa Dhesta* (Eleventh season)

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha* (Twelfth season)

It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishermen, this *pranatamangsa* plays essential roles in their lives not only to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 2.

Table 2. Calculation in determining *Mangsa* on *Pranatamangsa*

No	**Month**	**Calculation**				***Mangsa***
		Month	**Value**	**Calculation**		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 2 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1. It depicts *pranatamangsa* as a primary reference for farmers and fishers, it includes the formulas to determine the seasons and its units. This can be a reference for students and teachers in Yogyakarta.

Figure 1. Wheel of *Pramanamangsa*

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in day 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the proper days for organizing it and memoriam date of praying for the death (Pariyem, 2017).

1. Mathematical modeling for determining birth ceremonial

This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo five. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo five specifies the sacred day (Robiyanto & Puryandani, 2015). Modulo seven is used as in solar calendar there are 7 days, namely Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday. While, in Javanese sacred day (different name of days), there are only 5 days; Pahing, Pon, Wage, Kliwon, and Legi. Before the modern calendar, Javanese used these to name days.

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. Such year is divisible by four, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = day of birth - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = Day of birth

N = Year-n

s = Year today

q = Additional day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 4.

Table 4. Calculating the additional day

Days in a year	Additional day
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Days in a year (mod 5)

Sacred day in year-n = Sacred day of birth- [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN = Sacred day in year-n

u = Today's sacred day

n = Year-n

s = Year today

p = Additional day

k = Number of leap years

t = Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5) = 365 (mod 5) = 0

PN = u - [{(n-s) x p} + k] mod 5

= Wage - [{(2017-1945) x 0} + 18] mod 5

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days = Legi

Therefore, from the calculations, it can be concluded that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

a. Mathematical modeling on date of death ceremonial

On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 5.

Table 5. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H = Date of death ceremonial

a = Additional days

b = Mourn day in n by n = 3, 7, 40, 100, and 1000
C = Date of the death

b. Mathematical modeling in determining sacred day of a death person
In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 6.

Table 6. Model for calculating the sacred day of the death

The mourn day	**The value of the sacred day**	**Value of the day**	**Number of Increased *Pasaran* Days**
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 6, it concludes that:
Additional days for the sacred day = The Mourn day (mod 5) -1
The ceremonial sacred day = Dead day + additional sacred day
or it can be written as:

$$D = b \pmod{7} - 1$$
$$P = c + d$$

Information:
P = The sacred day of the death in year-n
d = Number of additional sacred days
b = The-n mourn day n = 3, 7, 40, 100, and 1000
c = The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 7.

Table 7. An example of the Mourn day of the death day

The-n mourn day	**The dead day**	**Additional day**	**The mourn day**
3	Friday	+ 2 days	Sunday

7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 8.

Table 8. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 9.

Table 9. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture pranatamangsa have added references and knowledge concerning the use of cultural contexts which are potential as starting points in learning mathematics. In line with this, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. Kemaro island legend can be used to teach statistics (Lestariningsih, Putri, & Darmawijoyo, 2012). In addition, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019) and Gundu for learning linear measurement (Wijaya, Doorman, & Keijze, 2011).

Integrating ethnomathematics can be helpful to make mathematics relevant and meaningful to students and might foster their performances. In the case of the low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study might be affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This led students to memorize formulas without knowing its meaning and not being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the problems and or environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

Yogyakarta's culture includes mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishermen. They predict which fish they will catch and tools to be used by studying natural phenomena. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo 5 and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. This study has shown a rich culture containing mathematical modelling which are potential to be used in learning mathematics topics such as patterns, modulo, and number sense. It is expended to be reference for educators in Yogyakarta to improve students understanding and relation of mathematics and their culture and lives.

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Dear Rully Charitas Indra Prahmana,

We have reached a decision regarding your submission to Journal on Mathematics Education, entitled "ETHNOMATHEMATICS: PRANATAMANGSA SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA". You would be pleased to know that your manuscript has been accepted for publication on August 30, 2020. The finalization procedure works as follows:
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ETHNOMATHEMATICS: *PRANATAMANGSA* SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA

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Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their problems and or environments. Along with its development, mathematics has been taught through formal education or schooling in the routine not flexible ways and far from students' social and cultural lives. Indonesia is rich with its culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators have not yet been aware of culture richness in the learning process to integrate it as the starting point. Hardly to be found in mathematics textbooks in Indonesia which put cultural context as starting points. Therefore, this study aimed to explore Yogyakarta's culture in terms of contexts that can be used in mathematics education. This is an ethnography study. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resources resource persons who understand the seasons, system, and calculation of birth and death days. This is to clarify the researcher's understanding of the literature. This study's results showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and birth-death dates. These are potential to be used as a starting point in learning mathematics.

Keywords: Mathematical Modelling, Yogyakarta Culture, Ethnomodeling, Seasons System, Birth and Death Dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: Pemodelan Matematika, Budya Yogyakarta, *Ethnomodeling*, Sistem Musim, Hari Kelahiran dan Kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but is influenced by historical aspects, environment, social, and geography, or we refer it as a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018).

However, mathematics becomes formal mathematics when it comes to formal education or schooling in routine-not flexible ways and far from cultures in which it developed and is taught (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So, mathematics learning becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoners, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning aims to make students love mathematics, get motivated and improve creativity in doing mathematics.

There are several ways to integrate ethnomathematics in teaching and learning (Rosa & Orey, 2017). One of the approaches is ethno-modeling which was firstly introduced by Bessanezi (2002). In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). Rosa and Orey (2013) stated that ethnomodelling would allow us to see mathematics performed holistically. In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring phenomenon around students' neighbourhood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a maritime country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This creates opportunities in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in students' culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called *pranatamangsa*. Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to sail for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which existin several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to study Yogyakarta's culture in mathematical modeling, which has the potential to be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture includes mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

The method used in this research is an ethnographic method, which is a method that describes the culture of a community (Spardley & McCurdy, 1989). Ethnography was chosen as the method in this study because it is in line with the aims of ethnomathematics which study ideas, methods, and techniques in a particular culture from the original view of members of that culture (Asher & D'Ambrosio, 1994; Shirley & Palhares, 2016). Ethnographic methods involve learning about cultures that see, hear, speak, and act in different ways and in ways that they find themselves (Spradley & McCurdy, 1989). Data collection was carried out by field studies and interviews with Mr. Riyadi and Mr. Gasiman, farmers and fishermen on the coast of Bugel, Panjatan, Kulon Progo to know, explore and clarify comprehensively about one of the bases for catching fish at sea such as predicting catch fish, tools, weather conditions, and risks, as well as a basis to farm in the fields, predict the kind of plant will be planted and predict the times when planting, harvesting and others.

In this study, uses three boundaries of the coverage area are used which are the basis for determining the research subject, that are community unity consisting of education that speaks one language or accent in the same language, community unity which is limited by the boundaries of an administrative political area and community unity which experiences one experience. the same history, as the limits that have been set in ethnographic research to show the authenticity of culture under study, there is no mixture with other cultures (Clifton. 0000; Koentjaradiningrat, 2016). Therefore, it was determined that the community unit to be studied was the original Yogyakarta people who used the same accent, that are the Javanese language, limited by the same administrative area, namely the Special Region of Yogyakarta and experienced the same historical experience, that is history when living, growing and developing in Yogyakarta.

Koentjaradiningrat (2016) explains that in ethnographic research there were seven main descriptions produced by ethnographers, that is language, technology systems, economic systems, social organizations, knowledge systems, arts, and religion. In this study, the researcher will focus on one main description, that is the knowledge system because, to dissect the techniques used by the community in making batik motifs, the researcher must observe and dive into the knowledge and technology systems to find the knowledge base used in the process catching fish and farming activities. Even so, it does not rule out that other cultural elements will also be studied because they are related to one another.

In conducting ethnomathematic exploration, researchers begin with four general questions that are the essence of ethnographic principles, that is "where to start looking?", "how to look?", "how to recognize that you have found something significant?", "how to understand what it is?". The results of data collection were collected in the form of pictures, videos, and field notes, then were analyzed to see the relationship between the mathematical knowledge system and culture and to see the mathematical conceptions that exist in the catching fish and farming activity. Then the findings are described in the results of this study. Based on these four general questions, the research stages are organized in Table 1.

Table 1. Design of Ethnography Research

General Questions	Initial Answers	Starting Point	Specific Activity
Where to start looking?	In the activities of catching fish and farming carried out by the people of Yogyakarta where there are mathematical practices in it.	Culture	Conducting interviews with people who have knowledge of Javanese culture in the Yogyakata community or those who catching fish and farming.
How to look?	Investigating aspects of catching fish and farmingof the people of Yogyakarta related to mathematics practice.	Alternative thinking, technology and knowledge system	Determine what ideas are contained in catching fish and farming activities of the people of Yogyakarta related to mathematics practice.
What it is?	Evidence (Results of alternative thinking in the previous process)	Philosophy of mathematics	Identifying characteristics in the activity of catching fish and farming Yogyakarta society related to mathematics practice. It shows that the activity of catching fish and farming activities for the people of Yogyakarta does have a mathematical character seen from the elements of

			knowledge and art systems used in everyday life.
What it means?	Valued important for culture and important value patterns for mathematics	Anthropologist	Describes the relationship between the two systems of mathematical knowledge and culture. Describe mathematical conceptions that exist in the activity of catching fish and farming for the people of Yogyakarta.

This is an ethnography that studies description of the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaradiningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaranigrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. This study only observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta. These respondents were purposively selected to gain more information based on their experiences. The interviews were conducted with semi-structured interview. The data from interviews were analyzed through content analysis to find the general ideas of pranatamangsa being used and helpful for them. The data from the documents were analyzed through content analysis and showed useful diagram depicting seasons division.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling used in the calculation in seasons system or *pranatamangsa*. to the calculation predict how much fish, types of fish will be caught and tools for fishing and farmers, and determine what types of crops they have to plan and the crop date. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units adjusted to cropping seasons. A year (365 days) is divided into four seasons related to seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for starting to have rain, *Mangsa Rendheng* for wet season, and *Mangsa Mareng* for the changing period (Kridalaksana, 2001; Gasiman, 2017). Besides, a year can be divided into 12 units of time-related to the Solar calendar. Each group has a different number of days and is indicated by natural phenomenon and constellation to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming activities and fishing. This is an essential reference for farmers and fishermen to determine the tools they will use. The seasons' divisions are as following (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa* (First season)

   It is to state the first season lasting for 22 days ranging from 22 June to 1 August. On the land, in this season, the temperature is cold and fluctuated, leaves are falling and no rain. Meanwhile, in the sea, the west stream and east wind (monsoon) are detected. Farmers plant "*palawija*" and fishermen look for fish such as tuna, yellowfin tuna, skipjack tuna, stingray and sailfish.
2. *Mangsa Karo* (Second season)

   It is the second season lasting for 23 days ranging from 2 August-24 August. On the land, trees are blooming, the temperature is cold, cracking soil surface, dried humidity. In the sea, the sea's surface is cold, east wind (monsoon) blows strongly and steadily west stream. Farmers plant "*palawija*," cleaning the weeds. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
3. *Mangsa Katelu* (Third season)

   It is the third season lasting for 24 days ranging from 25 August to 17 September. The land conditions are strong east wind (monsoon), falling flowers, tubers start to grow, and the cold temperature. The sea conditions are with cold surface water with murmured color and jellyfish appearing. In this season, the crop for "*palawija*" happens. The fishermen hunt for yellowfin tuna, skipjack tuna, and milk shark.
4. *Mangsa Kapat* (Fourth season)

   It is the fourth season lasting for 27 days ranging from 18 September to 12 October. The land conditions are mild east wind (monsoon), falling flowers, and the cold temperature. The sea conditions are indicated by changing steams, and wind direction murmured color seawater, the west wind blows mildly, and the tide calms down. In this season, the crop for "*palawija*" happens. The fishermen hunt for large head hairtail, tuna, skipjack tuna, black pomfret, and white pomfret.
5. *Mangsa Kalima* (Fifth season)

   It is the fifth season lasting for 27 days ranging from 13 October to 8 November. The land conditions are with rain, the figs are growing, and the wind blows mildly. The sea conditions are warm temperature, small shrimps appearing, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, tuna, Spanish mackerel, skipjack tuna, black pomfret, and white pomfret, anchovies, and lobster.

6. *Mangsa Kanem* (Sixth season)

   It is the sixth season lasting for 43 days ranging from 9 November to 21 December. The land conditions have mild rain, the plants are growing fruits, and the wind blows mildly. The sea conditions are warm, and the wind blows to the west direction, the stream flows to the east, and murmured color seawater. In this season, farmers seed paddies. The fishermen hunt for Spanish mackerel, black pomfret, and white pomfret, anchovies, and lobster.

7. *Mangsa Kapitu* (Seventh season)

   It is the seventh season lasting for 43 days ranging from 22 December to 2 February. The land conditions are with relatively weak wind, heavy rain, river flooding. The sea conditions are murmured color seawater, and the wind blows to the west. Sea stream flows to east. In this season, farmers seed paddies. The fishermen hunt for large head hairtail, snapper, little stingray, airdate, and lobster.

8. *Mangsa Kawolu* (Eighth season)

   It is the eight-season lasting for 27 days ranging from 3 February to 29 February. The land conditions are with the strong west wind and heavy rain. The sea conditions are strong west wind, weaker sea stream flows to the east, and murmured water sea. In this season, farmers' seed corns and the paddies are growing. The fishermen hunt for chub mackerel, pomfret, long head hairtail, stingray, and shrimps.

9. *Mangsa Kasanga* (Ninth season)

   It is the ninth season lasting for 25 days ranging from 1 March to 25 March. The land conditions are with undirected wind and rarely rain, but rivers still flood, the flowers start to fall. The sea conditions are with seagulls, murmured water sea, weak east stream, and weak tide. In this season, farmers wait for cropping the yellow paddies fields. The fishermen hunt for airdate, long head hairtail, pomfret, stingray, and shrimps.

10. *Mangsa Kasepuluh* (Tenth season)

    It is the tenth season lasting for 24 days ranging from 26 March to 18 April. The land conditions are with mild wind and birds' eggs hatching. The sea conditions are with the changing stream direction. In this season, farmers crop their paddies. The fishermen hunt for airdate, long head hairtail, Spanish mackerel, and shrimps.

11. *Mangsa Dhesta* (Eleventh season)

    It is the eleventh season lasting for 23 days ranging from 19 April to 11 May. The land conditions are with no rain and falling flowers. The sea conditions are with seagulls, and the west stream flows, the seawater glowing at night. In this season, farmers crop their paddies. The fishermen hunt for tuna, sailfish, marlin, and black profert.

12. *Mangsa Sadha* (Twelfth season)

    It is a twelfth season lasting for 41 days ranging from 12 May to 21 June. The land conditions are with no rain and falling leaves. In this season, farmers crop their plants. The fishermen hunt for marlin, tuna, and sailfish.

For Javanese people who work as farmers and fishermen, this *pranatamangsa* plays essential roles in their lives not only to understand the nature but also as ways to determine tools for them to catch fish, predicting the bad weather threatening them, predicting steam directions, and for farmers to discover time for seeding, growing, and cropping. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 2.

Table 2. Calculation in determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				***Mangsa***
		Month	**Value**	**Calculation**		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 2 determine the mathematical modeling on calculating *pranatamangsa* is:

1. For the seasons from January to June, the formula used is:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on the season wheel in Figure 1. It depicts *pranatamangsa* as a primary reference for farmers and fishers, it includes the formulas to determine the seasons and its units. This can be a reference for students and teachers in Yogyakarta.

Figure 1. Wheel of *Pramanamangsa*

Mathematical Modelling for Determining the Dates of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to calculate the dates for birth-death ceremonial. In Javanese culture, especially in Yogyakarta, the death is mourned in day 3, 7, 40, 100, and 100 after his/her dead. It is to remember and to pray for death (Suminah, 2017). Besides, Javanese also determine the proper days for organizing it and memoriam date of praying for the death (Pariyem, 2017).

1. Mathematical modeling for determining birth ceremonial

   This study revealed that the culture of people of Java, people determine and calculate precisely the date and good/sacred day for a specific year. This is used to determine the birth date to make memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo five. The same goes for the determining death day ceremonial, in determining the date and sacred day. In the year of n, modulo seven is used to determine the death date, and modulo five specifies the sacred day (Robiyanto & Puryandani, 2015). Modulo seven is used as in solar calendar there are 7 days, namely Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday. While, in Javanese sacred day (different name of days), there are only 5 days; Pahing, Pon, Wage, Kliwon, and Legi. Before the modern calendar, Javanese used these to name days.

Besides, in determining the birth-death dates and sacred day in a specified year, it is possible to meet a leap year having 366 days. Such year is divisible by four, that is how this year called. Therefore, if it reaches a leap year, we need to add one day. The detailed description is in Table 3.

Table 3. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 2, it concludes that:

Additional day = Days in a year (mod 7)

Day on year-n = day of birth - [{(Year-n – Year today) x Additional day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = Day of birth

N = Year-n

s = Year today

q = Additional day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the sacred day is described on Table 4.

Table 4. Calculating the additional day

Days in a year	**Additional day**
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Additional day = Days in a year (mod 5)

Sacred day in year-n = Sacred day of birth- [{(Year-n – Year Today x Additional day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN = Sacred day in year-n

u = Today's sacred day

n = Year-n

s = Year today

p = Additional day

k = Number of leap years

t = Days in a year (365 days)

An example of determining the date of birth ceremonial and sacred day in year-n is the following. A person was born on Thursday, 17 August 1945. His/her time of birth ceremonial in the year 2017 is:

Q = t (mod 7)

= 365 (mod 7)

= 1

HN = m - [{n-s) x q} + k] mod 7

= Thursday - [{(2017-1945) x 1} + 18] mod 7

= Thursday - [{72 x 1} + 18] mod 7

= Thursday - [72 + 18] mod 7

= Thursday - [90] mod 7

= Thursday - 6 days

= Friday

Meanwhile, his/her sacred day is:

P = t (mod 5) = 365 (mod 5) = 0

PN = u - [{(n-s) x p} + k] mod 5

= Wage - [{(2017-1945) x 0} + 18] mod 5

= Wage - [{72 x 0} + 18] mod 5

= Wage - [18] mod 5

= Wage - 3 days = Legi

Therefore, from the calculations, it can be concluded that the date of birth ceremonial for a person who was born on 17 August 1945 would be on Friday Legi.

2. Mathematical modelling in determining the date of death ceremonial

   This study revealed that in the culture of Yogyakarta, mourn to the dead person in day 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). An inherited culture like this is to memorize the family's death, so he/she could be prayed by the living members of the family or relatives. Predicting the date of death ceremony used mathematical modeling involving modulo 7 for the day and modulo 5 for the sacred day of the dead person. The detail is as follows.

   a. Mathematical modeling on date of death ceremonial

      On calculating the date of death ceremonial, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week is seven, and so the days in year-n are divided by seven and resulted in the remainder. It has no rest if it is divisible by 7, and then it has the remaining seven days. This remainder is subtracted by one, which is the dead day because this day is not included in the calculation. Then, it resulted in the number of days needed to be added on the date of death of what day it is in year-n. The detail description is in Table 5.

Table 5. Model of Death Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Additional day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Additional day = Mourn day (mod 7)-1

Day of ceremonial = Day of death + Additional day

or it can be written as:

$$a = b \pmod 7 - 1$$

$$H = c + a$$

Information:

H = Date of death ceremonial

a = Additional days

b = Mourn day in n by n = 3, 7, 40, 100, and 1000

C = Date of the death

b. Mathematical modeling in determining sacred day of a death person

In predicting the sacred day of the death, it applies mathematical modeling integrating modulo 5. Therefore, the days in a year n is divided by five, and not the remainder means it still has five days. The rest is then subtracted by one due to the dead day is not counted. Then, it results in the number of days to be added to the sacred day of the death to lament. The detail explanation is in Table 6.

Table 6. Model for calculating the sacred day of the death

The mourn day	The value of the sacred day	Value of the day	Number of Increased *Pasaran* Days
3	3 (mod 5) = 3	3	3 -1 = 2 means +2 sacred day days
7	7 (mod 5) = 7	7	7 -1 = 6 means, +7 sacred day days
40	40 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
100	100 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days
1000	1000 (mod 5) = 0	5	5 -1 = 4 means, +4 sacred day days

Based on the explanation from the mathematical modeling in Table 6, it concludes that:

Additional days for the sacred day = The Mourn day (mod 5) -1

The ceremonial sacred day = Dead day + additional sacred day

or it can be written as:

$$D = b \pmod{7} - 1$$

$$P = c + d$$

Information:

P = The sacred day of the death in year-n

d = Number of additional sacred days

b = The-n mourn day n = 3, 7, 40, 100, and 1000

c = The actual sacred day of the death

It is an example to calculate the mourning celebration and its sacred day for a person who died in Friday Legi. It is detailed in Table 7.

Table 7. An example of the Mourn day of the death day

The-n mourn day	The dead day	Additional day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 8.

Table 8. An example of the Mourn day of the sacred day

The-n mourn day	The sacred day	Additional day	The sacred day for the mourn
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday Legi will have a date of death ceremonial in Table 9.

Table 9. Result for sacred day and date of death ceremonial

The-n mourn day	The day of death ceremonial	The sacred day for the mourn
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture pranatamangsa have added references and knowledge concerning the use of cultural contexts which are potential as starting points in learning mathematics. In line with this, Maryati and Prahmana (2018) explored the angles concepts, measurement, and integer operations in the Kartini batik pattern. Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese sacred-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. Kemaro island legend can be used to teach statistics (Lestariningsih, Putri, & Darmawijoyo, 2012). In addition, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using kubuk manuk games (Risdiyanti, Prahmana, & Shahrill, 2019) and Gundu for learning linear measurement (Wijaya, Doorman, & Keijze, 2011).

Integrating ethnomathematics can be helpful to make mathematics relevant and meaningful to students and might foster their performances. In the case of the low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA) study might be affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, &

Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This led students to memorize formulas without knowing its meaning and not being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the problems and or environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

Yogyakarta's culture includes mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishermen. They predict which fish they will catch and tools to be used by studying natural phenomena. Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the dead person. They also celebrate their birthday by using sacred days to celebrate their birthday. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo 5 and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. This study has shown a rich culture containing mathematical modelling which are potential to be used in learning mathematics topics such as patterns, modulo, and number sense. It is expended to be reference for educators in Yogyakarta to improve students understanding and relation of mathematics and their culture and lives.

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[JME] Editor Decision - Ethnomathematics: Pranatamangsa System and the Birth-Death Ceremonial in Yogyakarta Inbox

Jme Fkip Matematika <jme@unsri.ac.id> — Thu, Dec 24, 2020, 7:22 AM

to me, yunianto_wahid, MILTON, DANIEL

Dear Dr. Rully Charitas Indra Prahmana,

We have decided on your submission to the Journal on Mathematics Education entitled **Ethnomathematics: Pranatamangsa System and the Birth-Death Ceremonial in Yogyakarta**. We decide to **accept** your paper.
Furthermore, we will proceed with your paper to the next step of the production process. Should you have any questions, please do not hesitate to contact us.
Thank you very much for your cooperation. I do really appreciate it.

Kind Regards,

Prof. Dr. Zulkardi
Editor in Chief
Journal on Mathematics Education

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Proses Editing dan Proofread pada tanggal 2 Januari 2021

[In Editing] Ethnomathematics: Pranatamangsa System and the Birth-Death Ceremonial in Yogyakarta Inbox

Jme Fkip Matematika <jme@unsri.ac.id> — Sat, Jan 2, 9:09 PM

to me

Dear Dr. Rully Charitas Indra Prahmana,

Your accepted manuscript has been edited, and our editorial team's layout needs to be proofread before being published. To ensure the timely publication of your document, we ask that you mark any typographical errors. It is important to us that your work reaches your intended readership as soon as possible.

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ETHNOMATHEMATICS: *PRANATAMANGSA* SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA

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Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators are not yet aware of this richness in the learning process to integrate it as the starting point. It is hard to find in mathematics textbooks in Indonesia, which put cultural context as starting points. Therefore, this study aims to explore Yogyakarta's culture in terms of contexts used in mathematics learning. It is an ethnography study. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resource persons who understand the seasons, system, and calculation of birth and death days. It is to clarify the researcher's understanding of the literature. This study showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and funerary dates. These models have the potential to be used as a starting point in learning mathematics.

Keywords: mathematical modelling, ethnomodeling, Yogyakarta culture, seasons system, birth and death dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: pemodelan matematika, *ethnomodeling*, budaya Yogyakarta, sistem musim, hari kelahiran dan kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but is influenced by historical aspects, environment, social, and geography, or we refer it as a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018; Utami, Sayuti, & Jailani, 2020). However, mathematics becomes formal when it comes to formal education or schooling in routine-not flexible ways and far from cultures in which it developed and is taught (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So, mathematics learning becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated Ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoners, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, ethnomathematics, as pedagogical innovation in mathematics teaching and learning aims to make students love mathematics, get motivated and improve creativity in doing mathematics.

There are several ways to integrate ethnomathematics in teaching and learning (Rosa & Orey, 2017). One of the approaches is ethno-modeling which was firstly introduced by Bassanezi (2002). In learning mathematics, the use of ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). Rosa and Orey (2013) stated that ethnomodelling would allow us to see mathematics perform holistically. In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring phenomena around students' neighborhood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This creates opportunities in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in students' culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called *pranatamangsa*. Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to sail for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which exist in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to study Yogyakarta's culture in mathematical modeling, which has the potential to be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture includes mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

The method used in this research is an ethnographic method, which is a method that describes the culture of a community (Spardley & McCurdy, 1989). Ethnography was chosen as the method in this study because it is in line with the aims of ethnomathematics which study ideas, methods, and techniques in a particular culture from the original view of members of that culture (Ascher & D'Ambrosio, 1994; Shirley & Palhares, 2016). Ethnographic methods involve learning about cultures that see, hear, speak, and act in different ways and in ways that they find themselves (Spradley & McCurdy, 1989). Data collection was carried out by field studies and interviews with Mr. Riyadi and Mr. Gasiman, farmers and fishermen on the coast of Bugel, Panjatan, Kulon Progo. From them, we learn, explore, and clarify comprehensively about one of the bases for catching fish at sea such as predicting catch fish, tools, weather conditions, and risks, as well as a basis to farm in the fields, predict the kind of plant to plant and predict the times to plant, harvest, and others.

In this study, three boundaries of the coverage area are used which are the basis for determining the research subject; that is community unity consisting of education that speaks one language or accent in the same language, community unity which is limited by the boundaries of an administrative political area and community unity has similar experiences. By using the same history, as the limits that have been set in ethnographic research to show the authenticity of culture under study, there is no mixture with other cultures (Koentjaraningrat, 2015). Therefore, it was determined that the community unit to be studied was the original Yogyakarta people who used the same accent (Javanese language), limited by the same administrative area, namely the Special Region of Yogyakarta and experienced the same historical experience, that is history when living, growing and developing in Yogyakarta.

Koentjaraningrat (2015) explains that in ethnographic research there were seven main descriptions produced by ethnographers, that is language, technology systems, economic systems, social organizations, knowledge systems, arts, and religion. In this study, the researcher will focus on one main description, that is the knowledge system because the researcher must observe and dive into the knowledge and technology systems to find the knowledge base used in the process of catching fish and farming activities. Even so, it does not rule out that other cultural elements will also be studied because they are related to one another.

In conducting ethnomathematical exploration, researchers begin with four general questions that are the essence of ethnographic principles, that is "where to start looking?", "how to look?", "how to recognize that you have found something significant?", "how to understand what it is?". The results of data collection were collected in the form of pictures, videos, and field notes, then were analyzed to see the relationship between the mathematical knowledge system and culture and to see the mathematical conceptions that exist in the catching fish and farming activity. Then the findings are described in the results of this study. Based on these four general questions, the research stages are organized in Table 1.

Table 1. Design of Ethnography Research

General Questions	Initial Answers	Starting Point	Specific Activity
Where to start looking?	In the activities of catching fish and farming carried out by the people of Yogyakarta where there are mathematical practices in it.	Culture	Conducting interviews with people who have knowledge of Javanese culture in the Yogyakarta community or those who catch fish and farming.
How to look?	Investigating aspects of catching fish and farming of the people of Yogyakarta related to mathematics practice.	Alternative thinking, technology and knowledge system	Determine what ideas are contained in catching fish and farming activities of the people of Yogyakarta related to mathematics practice.
What is it?	Evidence (Results of alternative thinking in the previous process)	Philosophy of mathematics	Identifying characteristics in the activity of catching fish and farming Yogyakarta society related to mathematics practice. It shows that the activity of catching fish and farming activities for the people of Yogyakarta does have a mathematical character seen from the elements of knowledge and art systems used in everyday life.
What does it mean?	Valued important for culture and important value patterns for mathematics	Anthropologist	Describes the relationship between the two systems of mathematical knowledge and culture.

		Describe mathematical conceptions that exist in the activity of catching fish and farming for the people of Yogyakarta.

This is an ethnography that studies the description of the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views. (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaraningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaraningrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. This study only observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta. These respondents were purposively selected to gain more information based on their experiences. The interviews were conducted with semi-structured interviews. The data from interviews were analyzed through content analysis to find the general ideas of *pranatamangsa* being used and helpful for them. The data from the documents were analyzed through content analysis and showed useful diagrams depicting seasons division.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling called *pranatamangsa*. This is a unique seasons calculator. Using this calculator, fishermen can tell which fish to catch, and which tools to use. farmers use this calculator to decide which crop to plant and when to harvest it. t It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units aligned with cropping seasons. It divides 365 days into four seasons, aligned with seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for pre-rainy season, *Mangsa Rendheng* for rainy season, and *Mangsa Mareng* for the transition season (Kridalaksana, 2001; Gasiman, 2017).

In addition, *Pranatamangsa* divides a year into 12 units of time, in accordance with the Solar calendar. Each unit has a different number of days. It indicates natural occurrences to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming and fishing as well as the tools they need. The seasons' divisions are as follows (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa* (First season)

   This is the first season, lasting for 22 days and starting from June 22nd to August 1st. In this season, natural occurrences on land are characterized by cool and fluctuating temperatures, fallen leaves and no rain, while natural occurrences in the sea are marked by the west currents and east winds. This condition is usually used by farmers to plant crops, while for fishermen, this condition is best to catch tuna, yellowfin, skipjack, stingray, and sailfish.
2. *Mangsa Karo* (Second season)

   It is the second season, lasting for 23 days, and starting from August 2nd to August 24th. In this season, natural occurrences on land are characterized by trees beginning to flower, cool temperatures, and dry air, while natural occurrences in the sea are characterized by cool sea surface, strong east winds and strong west currents. For farmers, it is to grow *palawija*. Farmers are usually clean weeds and wild plants that grow around the crops. As for fishermen, they catch yellowfin tuna and skipjack sharks.
3. *Mangsa Katelu* (Third season)

   It is the third season, lasting for 24 days, and starting from August 25th to September 17th. In this season, natural occurrences on land are characterized by strong east winds, fallen flowers, tubers begin to sprout and cool temperatures, while natural occurrences in the sea are characterized by cool sea surface, cloudy seawater, and jellyfish appearance. Farmers start harvesting their crops, while for fishermen, they catch yellowfin, tuna, and milk shark.
4. *Mangsa Kapat* (Fourth season)

   It is the fourth season, lasting for 27 days, starting from September 18th to October 12th. The natural occurrences on land are characterized by cold temperatures, fallen flowers and moderate winds, while natural occurrences at sea are characterized by changes in sea water currents and changes in wind direction, cloudy sea water, moderate west winds and calm waves. Farmers are still harvesting their crops, while for fishermen, they catch *layur* fish, mackerel, tuna, skipjack tuna, black pomfret, and white pomfret.
5. *Mangsa Kalima* (Fifth season)

   It is the fifth season, lasting for 27 days, starting from October 13th to November 8th. The natural occurrences on land are characterized by starting to rain, tree branches begin to sprout and the wind is blowing moderately, while the natural occurrences in the sea are characterized by warm sea surface, the emergence of tiny shrimp and cloudy seawater. Farmers begin to plant rice seeds in paddy fields, while for fishermen, they catch *layur* fish, mackerel, mackerel, tuna, white pomfret, black pomfret, anchovies, and lobster.

6. *Mangsa Kanem* (Sixth season)

   It is the sixth season, lasting for 43 days, starting from November 9th to December 21st. Natural occurrences on land in this season are characterized by moderate rainfall, trees that are beginning to bear fruit and moderate winds, while natural conditions at sea are characterized by warm sea surface, winds blowing westward, water currents moving east, and cloudy seawater. Farmers plant rice in the fields, while for fishermen, they catch black pomfret, white pomfret, mackerel, anchovies, and lobster.

7. *Mangsa Kapitu* (Seventh season)

   It is the seventh season, lasting for 43 days, starting from December 22nd to February 2nd. In this season, the natural occurrences land is marked by pouring rain and the river starts to flood, while the natural occurrences in the sea are characterized by turbid sea water, and wind blows to the west. Farmers plant rice in the fields while fishermen catch *layur* fish, snapper, small rays, *cucut*, *mayung*, and lobster.

8. *Mangsa Kawolu* (Eighth season)

   It is the eight-season, lasting for 27 days, starting from February 3rd to February 29th. In this season, the natural occurrences on land are characterized by strong west winds and heavy rain, while natural occurrences at sea are characterized by west winds blowing hard, eastern currents getting slower and the seawater becoming cloudy. Farmers are yet to harvest rice, while fishermen catch mackerel, pomfret, *layur*, *mayung*, stingray, *jerbung*, and prawns.

9. *Mangsa Kasanga* (Ninth season)

   It is the ninth season, lasting for 25 days, starting from March 1st to March 25th. In this season, the natural occurrences on land are marked by erratic wind direction, less rain though rivers are still flooded and flowers start to fall, while natural occurrences at sea are marked by the presence of seagulls, cloudy seawater, slow eastern current and small waves. Farmers can start preparing for rice harvest, but yet to harvest it. As for fishermen, catch *mayung*, *layur*, pomfret, *jerbung*, and shrimp.

10. *Mangsa Kasepuluh* (Tenth season)

    It is the tenth season, lasting for 24 days, starting from March 26th to April 18th. In this season, natural occurrences on land are characterized by moderate winds and birds start to hatch, while natural occurrences at sea are marked by changes in water currents. This is the time farmers harvest rice, while fishermen catch pomfret, snapper, *mayung*, *jerbung*, and shrimp.

11. *Mangsa Dhesta* (Eleventh season)

    It is the eleventh season, lasting for 23 days, starting from April 19th to May 11th. In this season, the natural occurrences on land are marked by no rain falling and the flowers are falling, while the natural occurrences at sea are marked by the presence of seagulls, western currents and lit up seawater at night. Farmers are still harvesting their rice, while fishermen catch tuna, marlin, sailfish, and black pomfret.

12. *Mangsa Sadha* (Twelfth season)

    It is the twelfth season, lasting for 41 days, starting from May 12th to June 21st. In this season, the natural occurrences on land are marked by no rain and fallen leaves. Farmers are still harvesting their rice, while fishermen catch marlin, tuna, and sailfish.

For Javanese who work as farmers and fishermen, *pranatamangsa* plays essential roles in their lives. Not only as a way to understand the nature but also to determine tools for them to catch fish, to predict the possible bad weather, to predict sea current directions, and to discover time for seeding, growing, and harvesting. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 2.

Table 2. Calculation in Determining *Mangsa* on *Pranatamangsa*

No	**Month**	**Calculation**				***Mangsa***
		Month	**Value**	**Calculation**		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 2 determine the mathematical modeling on calculating *pranatamangsa* is as follows:

1. For the seasons from January to June, the formula used is as follows:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is as follows:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on in Figure 1. It depicts *pranatamangsa* as a primary reference for farmers and fishers, it includes the formulas to determine the seasons and its units. This can be a reference for students and teachers in Yogyakarta.

Figure 1. Wheel of *Pramanamangsa*

Mathematical Modelling for Determining the Day of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to determine the days for birth-death ceremonies. In Javanese culture, especially in Yogyakarta, the death is mourned in day 3, 7, 40, 100, and 100 after one's death. It is to remember and to pray for deceased one (Suminah, 2017). Besides, Javanese also determine the proper days for organizing the funerary ceremony (Pariyem, 2017).

1. Mathematical modeling for determining one's *Neptu* day and value using day of birth

   In Javanese culture, people use a combination of national days (7 days) and Javanese (*Pasaran*) days (5 days) in their daily activities, such as Monday *Pahing*, Tuesday *Kliwon*, Wednesday *Pon*, Thursday *Wage*, Friday *Legi*, and others. In Javanese culture, each national and *pasaran* days have their own values, shown in Table 3.

Tabel 3. The sequence of national and *pasaran* days and its value

National Days	Value
Monday	4
Tuesday	3
Wednesday	7
Thursday	8
Friday	6
Saturday	9
Sunday	5

***Pasaran* Day**	**Value**
Legi	5
Pahing	9
Pon	7
Wage	4
Kliwon	8

In Javanese society, the term *neptu* or *weton* is also defined as the day of one's birth, which is described as the combination of national and *pasaran* days. The calculation of *neptu* value in Javanese society consists of the sum of the value of the national day and the *pasaran* value. For example, if someone was born on October 28, 1996, which is on Monday *Legi*, then the calculation of his *neptu* value is as follows:

Neptu value = Weighted value of national day + Weighted value of pasaran day
= Weighted value of Monday + Weighted value of *Legi*
= 4 + 5
= 9

This *neptu* calculation is usually used by Javanese people to predict human characteristics, a good day for making events, a good day for traveling, a good day for marriage, predicting compatibility of a prospective spouse, job suitability, and so on. The results of this prediction are written in a book called the *Primbon* Book, which is a book of ancestral heritage that contains predictions and teachings that come from the relationship between life and the universe (Utami, Sayuti, & Jailani, 2019). A number of these predictions are still used in Javanese society. Apart from reasoning from the human ratio of the relationship between life and the universe, some predictions in the *Primbon* book and/or warning predictions that have been used in people's daily lives can be explained rationally using mathematical modeling, such as prediction of birthdays, anniversaries day of death, and the prediction of the day of the particular year.

This study reveals that in the culture of Javanese, people determine and calculate precisely their *pasaran* day for a specific year. This is used to determine the birth date to make memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo five. This mathematical modeling involves modulo seven and modulo five. Given any year n, modulo seven is used to determine the national day, and modulo five determine its *pasaran* (Robiyanto & Puryandani, 2015). Modulo seven is used to determine days, as in the solar calendar; Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday. While, in Javanese, people call it *pancawara* (5 numbers), or *pasaran*. There are 5 days; *Pahing*, *Pon*, *Wage*, *Kliwon*, and *Legi*. Before the modern calendar, Javanese used *pasaran*to name days. Before the modern calendar, Javanese used these to name days.

In determining the *neptu* in a specified year, people need to know one's day of birth. It is possible to meet a leap year of 366 days. Such a year is divisible by four, that is how this year is called leap year. Therefore, we need to calculate how many leap years from the year of birth to the current year. For every leap year, we add one to the addition of day. The detailed description is in Table 4.

Table 4. Calculating the addition to day

Days in a year	Addition to day
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Addition to day = Days in a year (mod 7)

Day in year-n = day of birth - [{(Year-n – Year today) x Addition to day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n

m = Day of birth

N = Year-n

s = Year today

q = Addition to day

k = Number of leap years

t = Days in a year (365 days)

Meanwhile, the *pasaran* day is described on Table 5.

Table 5. Calculating the addition of day

Days in a year	Addition to day
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Addition to day = Days in a year (mod 5)

Pasaran day in year-n = *Pasaran* day of birth- [{(Year-n – Year Today x Addition to day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN = *Pasaran* day in year-n

u = Today's *pasaran* day

n = Year-n

s = Year today

p = Addition to day

k = Number of leap years

t = Days in a year (365 days)

An example of determining the date of birth ceremonial and *pasaran* day in year-n is the following. A person was born on Thursday, 17 August 1945. His birth ceremonial in the year 2017 is on:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his *pasaran* day is:

P = t (mod 5) = 365 (mod 5) = 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5
= Wage - [{72 x 0} + 18] mod 5
= Wage - [18] mod 5
= Wage - 3 days
= Legi

Therefore, from the calculation above, it can be concluded that the *neptu* day date for a person who was born on 17 August 1945 would be on Friday *Legi*.

2. Mathematical modelling in determining the day of funerary ceremony using the death day of the deceased one

This study reveals that in the culture of Yogyakarta, families mourn the deceased 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). This is to memorize the family of one family members' death, so they can pray for the deceased one. Determining the day of funerary ceremony uses mathematical modeling involving modulo 7 for the 7-day-of-the-week and modulo 5 for the *pasaran* day of the deceased one. The details are as follows.

a. Mathematical modeling on determining the day of funerary ceremony

On calculating the day of the funerary ceremony, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week being seven, and so the days in year-n are divided by seven and resulted in the remainder. If it is divisible by 7, and then it has the remainder seven. Then the remainder is subtracted by one, in which we don't take deceased day into account. It resulted in the number of days needed to be added to the day of death in the year-n. The detailed description is in Table 6.

Table 6. Model of Funerary Day Calculation

The Mourn Day	Calculation of its value	Value of the day	Addition to day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 6, it concludes that:

Addition to day = Mourn day (mod 7)-1

Funerary day ceremony = Day of death + Addition to day or it can be written as:

$$a = b \text{ (mod 7)-1}$$
$$H = c + a$$

Information:

H = Funerary day ceremony
a = Addition to day
b = Mourn day in n by n = 3, 7, 40, 100, and 1000
c = Day of death

b. Mathematical modeling in determining *pasaran* day of a death person

In predicting the *pasaran* day of the deceased one, we apply mathematical modeling integrating modulo 5. Therefore, for those days in a year n which is divisible by five, and it has remainder five (Utami, Sayuti, & Jailani, 2019). The remaining is then subtracted by one because we don't take the deceased day into account. Then, it results in the number of days to be added to the *pasaran* day of the deceased one. The detailed explanation is in Table 7.

Table 7. Model for calculating the *pasaran* day of the deceased one

The mourn day	The value of the *pasaran* day	Value of the day	Number of Addition to *Pasaran* Days
3	3 (mod 5) = 3	3	3 - 1 = 2 means, +2 *pasaran* day
7	7 (mod 5) = 7	7	7 - 1 = 6 means, +7 *pasaran* day
40	40 (mod 5) = 0	5	5 - 1 = 4 means, +4 *pasaran* day
100	100 (mod 5) = 0	5	5 - 1 = 4 means, +4 *pasaran* day
1000	1000 (mod 5) = 0	5	5 - 1 = 4 means, +4 *pasaran* day

Based on the explanation from the mathematical modeling in Table 7, it concludes that:

Addition to the *pasaran* day = The Mourn day (mod 5) -1

The ceremonial *pasaran* day = Deceased day + addition to *pasaran* day

or it can be written as:

$$D = b \text{ (mod 7)-1}$$
$$P = c + d$$

Information:

P = The *pasaran* day of the deceased one in year-n
d = Addition to *pasaran* days
b = The-n mourn day n = 3, 7, 40, 100, and 1000
c = The actual *pasaran* day of the deceased one

It is an example to calculate the mourning celebration and its *pasaran* day for a person who died on Friday *Legi*. It is detailed in Table 8.

Table 8. An example of the Mourn day of the death day

The-n mourn day	The dead day	Addition to day	The mourn day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 9.

Table 9. An example of the Mourn day of the *pasaran* day

The-n mourn day	The *pasaran* day	Addition to day	The *pasaran* day for the funerary ceremony
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday *Legi* will have funerary ceremony day in Table 10.

Table 10. Result for *pasaran* day of funerary ceremony

The-n mourn day	The day of funerary ceremony	The *pasaran* day for the funerary ceremony
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture *pranatamangsa* have added references and knowledge concerning the use of cultural contexts which are potential as starting points in learning mathematics. In Hawaii, there is a Hawaiian moon calendar whose function is similar to *pranatamangsa* in Yogyakarta. It turns out to be used well in learning mathematics based on past, present, and future Hawaiian mathematics culture, as an effort to prepare future leaders with a solid foundation in understanding the wisdom of Hawaiian ancestors by using mathematical modeling elements (Kaomea, 2019). Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese *pasaran*-fortune day (primbon). Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture. Kemaro island legend can be used to teach statistics (Lestariningsih, Putri, & Darmawijoyo, 2012). In addition, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011) and Social arithmetic using *kubuk manuk* games (Risdiyanti, Prahmana, & Shahrill, 2019) and Gundu for learning linear measurement (Wijaya, Doorman, & Keijzer, 2011).

Integrating ethnomathematics can be helpful to make mathematics relevant, meaningful to students, and foster their performances. If we look into the case of the low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA), it might be affected by teachers who have not integrated students' social and cultural life in learning mathematics. Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014; Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). This led students to memorize formulas without knowing its meaning and not being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture. Mathematics exists because of the need for humans to respond to the problems and or environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013).

CONCLUSION

Yogyakarta's culture includes mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishermen. They predict which fish they will catch and tools to be used by studying natural phenomena.

Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the deceased one. They also celebrate their birthday by using *neptu* days. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo 5 and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. This study has shown a rich culture containing mathematical modelling which are potential to be used in learning mathematics topics such as patterns, modulo, and number sense. It is expanded to be a reference for educators in Yogyakarta to improve students' understanding and relation of mathematics and their culture and lives.

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ETHNOMATHEMATICS: *PRANATAMANGSA* SYSTEM AND THE BIRTH-DEATH CEREMONIAL IN YOGYAKARTA

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Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators are not yet aware of this richness in the learning process to integrate it as the starting point. It is hard to find in mathematics textbooks in Indonesia, which put cultural context as starting points. Therefore, this study aims to explore Yogyakarta's culture in terms of contexts used in mathematics learning. It is an ethnography study. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resource persons who understand the seasons, system, and calculation of birth and death days. It is to clarify the researcher's understanding of the literature. This study showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and funerary dates. These models have the potential to be used as a starting point in learning mathematics.

Keywords: mathematical modelling, ethnomodeling, Yogyakarta culture, seasons system, birth and death dates

Abstrak

Keberadaan matematika bersumber dari gagasan, cara, dan teknik manusia untuk merespons lingkungan mereka. Seiring dengan perkembangannya, matematika telah diajarkan melalui pendidikan formal atau sekolah dengan cara yang tidak fleksibel dan jauh dari kehidupan sosial dan budaya siswa. Indonesia kaya dengan budayanya, termasuk Daerah Istimewa Yogyakarta (DIY). Itu disebut kota budaya. Pendidik belum menyadari kekayaan ini dalam proses pembelajaran untuk mengintegrasikannya sebagai titik awal. Oleh karena itu, penelitian ini bertujuan untuk mengeksplorasi budaya Yogyakarta dalam konteks yang dapat digunakan dalam pembelajaran matematika. Penelitian ini merupakan studi etnografi dengan *ethnomodelling*. Selanjutnya, data dikumpulkan melalui studi literatur, observasi lapangan, dan wawancara dengan narasumber yang memahami musim, sistem, dan perhitungan hari kelahiran dan kematian. Ini untuk memperjelas pemahaman peneliti tentang literatur. Hasil penelitian ini menunjukkan bahwa masyarakat Yogyakarta menggunakan pemodelan matematika untuk menentukan sistem musim dan tanggal kelahiran dan kematian. Hal ini berpotensi untuk digunakan sebagai titik awal dalam belajar matematika.

Kata kunci: pemodelan matematika, *ethnomodeling*, budaya Yogyakarta, sistem musim, hari kelahiran dan kematian

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Mathematics stems from ways, styles, and techniques developed by humans to respond to environments such as seeking explanations, understanding, experiences, and solutions to surrounding phenomena (Freudhental, 2006; D'Ambrosio, 2007; Rosa & Orey, 2016; D'Ambrosio, 2016). Mathematics does not stand alone but is influenced by historical aspects, environment, social, and geography, or we refer it as a culture where humans evolve in life processes (D'Ambrosio, 2016; Risdiyanti & Prahmana, 2018; Utami, Sayuti, & Jailani, 2020). However, mathematics becomes formal when it comes to formal education or schooling in routine-not flexible ways and far from cultures in which it developed and is taught (Alangui, 2010; Muhtadi, Sukirwan, Warsito & Prahmana, 2017). This issue is related to western colonization, which tried to hegemon the knowledge in the world (D'Ambrosio, 2007; Joseph 2010; Rosa & Orey, 2016). So, mathematics learning becomes transferring knowledge, and students receive it without any reflective thinking and not knowing the use of mathematics in daily life.

Based on how mathematics has been taught at schools, reflecting on how mathematics developed, D'Ambrosio (1985) initiated Ethnomathematics as a solution. Ethnomathematics is a way to learn and combine ideas, ways, techniques that have been used and developed by socio-culture or members of different cultures (D'Ambrosio, 2016; Rosa & Orey, 2016). Ethnomathematics tries to reposition mathematics to be rooted in different cultures, accommodating different ideas so that students become critical reasoners, democratic, and tolerant (D'Ambrosio, 2016; Zevenbergen, 2001). Therefore, Ethnomathematics, as pedagogical innovation in mathematics teaching and learning aims to make students love mathematics, get motivated and improve creativity in doing mathematics.

There are several ways to integrate Ethnomathematics in teaching and learning (Rosa & Orey, 2017). One of the approaches is ethno-modeling which was firstly introduced by Bassanezi (2002). In learning mathematics, the use of Ethnomathematics and mathematical modeling towards ideas, ways, and techniques from what societies have developed is expected to be an alternative for introducing surrounding lives to students (Rosa & Orey, 2016). Rosa and Orey (2013) stated that ethnomodelling would allow us to see mathematics perform holistically. In this way, it is possible to critically explore local mathematics by appreciating the diverse cultural values of different societies (Abdullah, 2017). Therefore, mathematics learning can be initiated by critically exploring phenomena around students' neighborhood and model them mathematically, to develop awareness and critical reasoning, and get motivated.

Indonesia is a country with abundant cultures embedding mathematical ideas, ways, and techniques using mathematical modeling. This creates opportunities in mathematics education to use local contexts and to boost students' critical reasoning and interest by reinventing mathematics rooted in students' culture existing in their surroundings to get the benefit from it. One of the mathematical phenomena in Yogyakarta is the seasons' system repeating every year or called *pranatamangsa*. Besides, Yogyakarta's people still organize birth and death Memoriam ceremonies and determine when it should be done by using a mathematical calculation. Exploring mathematical modeling in *pranatamangsa* and determining the dates for birth-death ceremonial can be contexts for learning mathematics.

Exploring mathematical modeling in Indonesia has been documented by some researchers. Abdullah (2017) studied mathematical modeling on the clock and measuring unit in Tasikmalaya, the Sunda district. Furthermore, there are several ethnics which implemented of Ethnomathematics in their life in Cipatujah, West Java, for example, they apply the traditional mathematical concept in the way they determine the time to sail for fishing, and the way they construct their houses (Kusuma, Dewanto, Ruchjana, & Abdullah, 2017). The motifs of batik are an Ethnomathematics context related to lines, angles, triangles, quadrilaterals, circles, and transformation geometry, which exist in several cultures in Indonesia (Risdiyanti & Prahmana, 2018; Lestari, Irawan, Rahayu, & Parwati, 2018; Pramudita & Rosnawati, 2019; Irawan, Lestari, Rahayu, & Wulan, 2019). However, few researchers have explored mathematical modeling in Yogyakarta's literature. Therefore, the researchers aimed to study Yogyakarta's culture in mathematical modeling, which has the potential to be used as a starting point to learn mathematics.

The next sections explain the methodology, how the data was collected. Furthermore, results and discussion of the seasons' system and a birth-death ceremonial will be described. The results of this study then were compared to previous related studies in different areas. In conclusion, this study revealed that Yogyakarta's culture includes mathematical ideas, ways, and techniques that can be explored through mathematical modeling.

METHOD

The method used in this research is an ethnographic method, which is a method that describes the culture of a community (Spardley & McCurdy, 1989). Ethnography was chosen as the method in this study because it is in line with the aims of Ethnomathematics which study ideas, methods, and techniques in a particular culture from the original view of members of that culture (Ascher & D'Ambrosio, 1994; Shirley & Palhares, 2016). Ethnographic methods involve learning about cultures that see, hear, speak, and act in different ways and in ways that they find themselves (Spradley & McCurdy, 1989). Data collection was carried out by field studies and interviews with Mr. Riyadi and Mr. Gasiman, farmers and fishermen on the coast of Bugel, Panjatan, Kulon Progo. From them, we learn, explore, and clarify comprehensively about one of the bases for catching fish at sea such as predicting catch fish, tools, weather conditions, and risks, as well as a basis to farm in the fields, predict the kind of plant to plant and predict the times to plant, harvest, and others.

In this study, three boundaries of the coverage area are used which are the basis for determining the research subject; that is community unity consisting of education that speaks one language or accent in the same language, community unity which is limited by the boundaries of an administrative political area and community unity has similar experiences. By using the same history, as the limits that have been set in ethnographic research to show the authenticity of culture under study, there is no mixture with other cultures (Koentjaraningrat, 2015). Therefore, it was determined that the community unit to be studied was the original Yogyakarta people who used the same accent (Javanese language), limited by the same administrative area, namely the Special Region of Yogyakarta and experienced the same historical experience, that is history when living, growing and developing in Yogyakarta.

Koentjaraningrat (2015) explains that in ethnographic research there were seven main descriptions produced by ethnographers, that is language, technology systems, economic systems, social organizations, knowledge systems, arts, and religion. In this study, the researcher will focus on one main description, that is the knowledge system because the researcher must observe and dive into the knowledge and technology systems to find the knowledge base used in the process of catching fish and farming activities. Even so, it does not rule out that other cultural elements will also be studied because they are related to one another.

In conducting ethnomathematical exploration, researchers begin with four general questions that are the essence of ethnographic principles, that is "where to start looking?", "how to look?", "how to recognize that you have found something significant?", "how to understand what it is?". The results of data collection were collected in the form of pictures, videos, and field notes, then were analyzed to see the relationship between the mathematical knowledge system and culture and to see the mathematical conceptions that exist in the catching fish and farming activity. Then the findings are described in the results of this study. Based on these four general questions, the research stages are organized in Table 1.

Table 1. Design of Ethnography Research

General Questions	Initial Answers	Starting Point	Specific Activity
Where to start looking?	In the activities of catching fish and farming carried out by the people of Yogyakarta where there are mathematical practices in it.	Culture	Conducting interviews with people who have knowledge of Javanese culture in the Yogyakarta community or those who catch fish and farming.
How to look?	Investigating aspects of catching fish and farming of the people of Yogyakarta related to mathematics practice.	Alternative thinking, technology and knowledge system	Determine what ideas are contained in catching fish and farming activities of the people of Yogyakarta related to mathematics practice.
What is it?	Evidence (Results of alternative thinking in the previous process)	Philosophy of mathematics	Identifying characteristics in the activity of catching fish and farming Yogyakarta society related to mathematics practice. It shows that the activity of catching fish and farming activities for the people of Yogyakarta does have a mathematical character seen from the elements of knowledge and art systems used in everyday life.
What does it mean?	Valued important for culture and important value patterns for mathematics	Anthropologist	Describes the relationship between the two systems of mathematical knowledge and culture.

	Describe mathematical conceptions that exist in the activity of catching fish and farming for the people of Yogyakarta.

This is an ethnography that studies the description of the life of people in a culture community (Spradley & McCurdy, 1989). This method fits the Ethnomathematics study as it is to understand perspectives, ideas, ways techniques of the members from members' views (Spradley & McCurdy, 1989; Ascher & D'Ambrosio, 1994; Koentjaraningrat, 2015; Shirley & Palhares, 2016). This is in line with the research aim; to explore mathematical ideas, ways, and techniques of Yogyakarta culture concerning mathematical modeling. Koentjaraningrat (2015) described seven cultural aspects that can be the focus on ethnography; languages, systems of technology, the system of economics, social organization, a system of knowledge, arts, and religion. This study only observes and describes the system of knowledge of Yogyakarta's culture.

In this study, data were collected through field observation, literature review, documentation, and interview with Mr. Gasiman and Mr. Slamet Riyadi. They are a farmer and fisherman respectively in Bugel, Panjatan, Kulon Progo district to discuss *pranatamangsa*. Another conversation was with Mrs. Suminah and Mrs. Pariyem in Karangsari village, Pengasih sub-district, Kulon Progo district, to review the determination of dates for birth-death ceremonial in Yogyakarta. These respondents were purposively selected to gain more information based on their experiences. The interviews were conducted with semi-structured interviews. The data from interviews were analyzed through content analysis to find the general ideas of *pranatamangsa* being used and helpful for them. The data from the documents were analyzed through content analysis and showed useful diagrams depicting seasons division.

RESULTS AND DISCUSSION

The results showed that Yogyakarta's culture has mathematical modeling called *pranatamangsa*. This is a unique seasons calculator. Using this calculator, fishermen can tell which fish to catch, and which tools to use. Farmers use this calculator to decide which crop to plant and when to harvest it. It is also found that mathematical modeling is used in determining dates for birth-death ceremonial.

Mathematical Modeling of Pranatamangsa in Yogyakarta

Pranatamangsa is a season system dividing periods in a year into smaller units aligned with cropping seasons. It divides 365 days into four seasons, aligned with seasons for farming. These four periods are also called *Mangsa*, such as *Mangsa Ketiga* for dry season, *Mangsa Labuh* for pre-rainy season, *Mangsa Rendheng* for rainy season, and *Mangsa Mareng* for the transition season (Kridalaksana, 2001; Gasiman, 2017).

In addition, *pranatamangsa* divides a year into 12 units of time, in accordance with the Solar calendar. Each unit has a different number of days. It indicates natural occurrences to determine the seasons. *Pranatamangsa* is still used and believed by Javanese to do farming and fishing as well as the tools they need. The seasons' divisions are as follows (Partosuwiryo, 2013; Riyadi, 2017; Gasiman, 2017):

1. *Mangsa Kasa* (First season)

   This is the first season, lasting for 22 days and starting from June 22nd to August 1st. In this season, natural occurrences on land are characterized by cool and fluctuating temperatures, fallen leaves and no rain, while natural occurrences in the sea are marked by the west currents and east winds. This condition is usually used by farmers to plant crops, while for fishermen, this condition is best to catch tuna, yellowfin, skipjack, stingray, and sailfish.
2. *Mangsa Karo* (Second season)

   It is the second season, lasting for 23 days, and starting from August 2nd to August 24th. In this season, natural occurrences on land are characterized by trees beginning to flower, cool temperatures, and dry air, while natural occurrences in the sea are characterized by cool sea surface, strong east winds and strong west currents. For farmers, it is to grow *palawija*. Farmers are usually clean weeds and wild plants that grow around the crops. As for fishermen, they catch yellowfin tuna and skipjack sharks.
3. *Mangsa Katelu* (Third season)

   It is the third season, lasting for 24 days, and starting from August 25th to September 17th. In this season, natural occurrences on land are characterized by strong east winds, fallen flowers, tubers begin to sprout and cool temperatures, while natural occurrences in the sea are characterized by cool sea surface, cloudy seawater, and jellyfish appearance. Farmers start harvesting their crops, while for fishermen, they catch yellowfin, tuna, and milk shark.
4. *Mangsa Kapat* (Fourth season)

   It is the fourth season, lasting for 27 days, starting from September 18th to October 12th. The natural occurrences on land are characterized by cold temperatures, fallen flowers and moderate winds, while natural occurrences at sea are characterized by changes in sea water currents and changes in wind direction, cloudy sea water, moderate west winds and calm waves. Farmers are still harvesting their crops, while for fishermen, they catch *layur* fish, mackerel, tuna, skipjack tuna, black pomfret, and white pomfret.
5. *Mangsa Kalima* (Fifth season)

   It is the fifth season, lasting for 27 days, starting from October 13th to November 8th. The natural occurrences on land are characterized by starting to rain, tree branches begin to sprout and the wind is blowing moderately, while the natural occurrences in the sea are characterized by warm sea surface, the emergence of tiny shrimp and cloudy seawater. Farmers begin to plant rice seeds in paddy fields, while for fishermen, they catch *layur* fish, mackerel, mackerel, tuna, white pomfret, black pomfret, anchovies, and lobster.

6. *Mangsa Kanem* (Sixth season)

   It is the sixth season, lasting for 43 days, starting from November 9th to December 21st. Natural occurrences on land in this season are characterized by moderate rainfall, trees that are beginning to bear fruit and moderate winds, while natural conditions at sea are characterized by warm sea surface, winds blowing westward, water currents moving east, and cloudy seawater. Farmers plant rice in the fields, while for fishermen, they catch black pomfret, white pomfret, mackerel, anchovies, and lobster.

7. *Mangsa Kapitu* (Seventh season)

   It is the seventh season, lasting for 43 days, starting from December 22nd to February 2nd. In this season, the natural occurrences land is marked by pouring rain and the river starts to flood, while the natural occurrences in the sea are characterized by turbid sea water, and wind blows to the west. Farmers plant rice in the fields while fishermen catch *layur* fish, snapper, small rays, *cucut*, *mayung*, and lobster.

8. *Mangsa Kawolu* (Eighth season)

   It is the eight-season, lasting for 27 days, starting from February 3rd to February 29th. In this season, the natural occurrences on land are characterized by strong west winds and heavy rain, while natural occurrences at sea are characterized by west winds blowing hard, eastern currents getting slower and the seawater becoming cloudy. Farmers are yet to harvest rice, while fishermen catch mackerel, pomfret, *layur*, *mayung*, stingray, *jerbung*, and prawns.

9. *Mangsa Kasanga* (Ninth season)

   It is the ninth season, lasting for 25 days, starting from March 1st to March 25th. In this season, the natural occurrences on land are marked by erratic wind direction, less rain though rivers are still flooded and flowers start to fall, while natural occurrences at sea are marked by the presence of seagulls, cloudy seawater, slow eastern current and small waves. Farmers can start preparing for rice harvest, but yet to harvest it. As for fishermen, they catch *mayung*, *layur*, pomfret, *jerbung*, and shrimp.

10. *Mangsa Kasepuluh* (Tenth season)

    It is the tenth season, lasting for 24 days, starting from March 26th to April 18th. In this season, natural occurrences on land are characterized by moderate winds and birds start to hatch, while natural occurrences at sea are marked by changes in water currents. This is the time farmers harvest rice, while fishermen catch pomfret, snapper, *mayung*, *jerbung*, and shrimp.

11. *Mangsa Dhesta* (Eleventh season)

    It is the eleventh season, lasting for 23 days, starting from April 19th to May 11th. In this season, the natural occurrences on land are marked by no rain falling and the flowers are falling, while the natural occurrences at sea are marked by the presence of seagulls, western currents and lit up seawater at night. Farmers are still harvesting their rice, while fishermen catch tuna, marlin, sailfish, and black pomfret.

12. *Mangsa Sadha* (Twelfth season)

    It is the twelfth season, lasting for 41 days, starting from May 12th to June 21st. In this season, the natural occurrences on land are marked by no rain and fallen leaves. Farmers are still harvesting their rice, while fishermen catch marlin, tuna, and sailfish.

For Javanese who work as farmers and fishermen, *pranatamangsa* plays essential roles in their lives. Not only as a way to understand the nature but also to determine tools for them to catch fish, to predict the possible bad weather, to predict sea current directions, and to discover time for seeding, growing, and harvesting. This *pranatamangsa* is related to mathematical modeling. For simplicity, the *pranatamangsa* is formulated in Table 2.

Table 2. Calculation in Determining *Mangsa* on *Pranatamangsa*

No	Month	Calculation				***Mangsa***
		Month	**Value**	**Calculation**		
1	January-June	January	1		1 + 6 = 7	*Mangsa Kapitu*
		February	2		2 + 6 = 8	*Mangsa Kawolu*
		March	3		3 + 6 = 9	*Mangsa Kasanga*
		April	4	+ 6	4 + 6 = 10	*Mangsa Kasepuluh*
		May	5		5 + 6 = 11	*Mangsa Dhestha*
		June	6		6 + 6 = 12	*Mangsa Sadha*
		July	7		7-6 = 1	*Mangsa Kasa*
2	July-December	August	8		8-6 = 2	*Mangsa Karo*
		September	9		9-6 = 3	*Mangsa Katelu*
		October	10	- 6	10-6 = 4	*Mangsa Kapat*
		November	11		11-6 = 5	*Mangsa Kalima*
		December	12		12-6 = 6	*Mangsa Kanem*

Table 2 determine the mathematical modeling on calculating *pranatamangsa* is as follows:

1. For the seasons from January to June, the formula used is as follows:

   Mangsa = Value of the month (January– June) + 6

2. For the seasons from July to December, the formula used is as follows:

   Mangsa = Value of the month (July - December) – 6

The detailed explanation of the *pranatamangsa* is depicted on in Figure 1. It depicts *pranatamangsa* as a primary reference for farmers and fishers, and includes the formulas to determine the seasons and its units. This can be a reference for students and teachers in Yogyakarta.

Figure 1. Wheel of *Pranatamangsa*

Mathematical Modelling for Determining the Day of Birth-Death Ceremonial

People of Yogyakarta still use this mathematical model to determine the days for birth-death ceremonies. In Javanese culture, especially in Yogyakarta, the death is mourned in day 3, 7, 40, 100, and 100 after one's death. It is to remember and to pray for deceased one (Suminah, 2017). Besides, Javanese also determine the proper days for organizing the funerary ceremony (Pariyem, 2017).

1. Mathematical modeling for determining one's *Neptu* day and value using day of birth

In Javanese culture, people use a combination of national days (7 days) and Javanese (*Pasaran*) days (5 days) in their daily activities, such as Monday *Pahing*, Tuesday *Kliwon*, Wednesday *Pon*, Thursday *Wage*, Friday *Legi*, and others. In Javanese culture, each national and *pasaran* days have their own values, shown in Table 3.

Table 3. The Sequence of National and *Pasaran* Days and Its Value

National Days	Value
Monday	4
Tuesday	3
Wednesday	7
Thursday	8
Friday	6
Saturday	9
Sunday	5

Pasaran Day	Value
Legi	5
Pahing	9
Pon	7
Wage	4
Kliwon	8

In Javanese society, the term *neptu* or *weton* is also defined as the day of one's birth, which is described as the combination of national and *pasaran* days. The calculation of *neptu* value in Javanese society consists of the sum of the value of the national day and the *pasaran* value. For example, if someone was born on October 28, 1996, which is on Monday *Legi*, then the calculation of his *neptu* value is as follows:

Neptu value = Weighted value of national day + Weighted value of *pasaran* day
= Weighted value of Monday + Weighted value of *Legi*
= 4 + 5
= 9

This *neptu* calculation is usually used by Javanese people to predict human characteristics, a good day for making events, a good day for traveling, a good day for marriage, predicting compatibility of a prospective spouse, job suitability, and so on. The results of this prediction are written in a book called the *Primbon* Book, which is a book of ancestral heritage that contains predictions and teachings that come from the relationship between life and the universe (Utami, Sayuti, & Jailani, 2019). A number of these predictions are still used in Javanese society. Apart from reasoning from the human ratio of the relationship between life and the universe, some predictions in the *Primbon* book and/or warning predictions that have been used in people's daily lives can be explained rationally using mathematical modeling, such as prediction of birthdays, anniversaries day of death, and the prediction of the day of the particular year.

This study reveals that in the culture of Javanese, people determine and calculate precisely their *pasaran* day for a specific year. This is used to determine the birth date to make memoriam date for praying him/her on the localized wisdom birthday. This mathematical modeling involves modulo seven and modulo five. Given any year n, modulo seven is used to determine the national day, and modulo five determine its *pasaran* (Robiyanto & Puryandani, 2015). Modulo seven is used to determine days, as in the solar calendar; Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday. While, in Javanese, people call it *pancawara* (5 numbers), or *pasaran*. There are 5 days; *Pahing*, *Pon*, *Wage*, *Kliwon*, and *Legi*. Before the modern calendar, Javanese used *pasaran* to name days.

In determining the *neptu* in a specified year, people need to know one's day of birth. It is possible to meet a leap year of 366 days. Such a year is divisible by four, that is how this year is called leap year. Therefore, we need to calculate how many leap years from the year of birth to the current year. For every leap year, we add one to the addition of day. The detailed description is in Table 4.

Table 4. Calculating the Addition to Day

Days in a Year	Addition to Day
365	365 (mod 7) = 1 means +1

Based on the explanation from the mathematical modeling in Table 4, it concludes that:

Addition to day = Days in a year (mod 7)

Day in year-n = day of birth - [{(Year-n – Year today) x Addition to day} + Number of leap years] mod 7

or it can be written as:

$$q = t \pmod 7$$

$$HN = m - [\{(n-s) \times q\} + k] \bmod 7$$

Information:

HN = Day in the year-n
m = Day of birth
N = Year-n
s = Year today
q = Addition to day
k = Number of leap years
t = Days in a year (365 days)

Meanwhile, the *pasaran* day is described on Table 5.

Table 5. Calculating the Addition of Day

Days in a Year	**Addition to Day**
365	365 (mod 5) = 0 means +5

Based on the explanation from the mathematical modeling in Table 5, it concludes that:

Addition to day = Days in a year (mod 5)

Pasaran day in year-n = *Pasaran* day of birth- [{(Year-n – Year Today x Addition to day} + number of leap years] mod 5

or it can be written as:

p = t (mod 5)

PN = u - [{n-s) - p} + (k + 1)] mod 5

Information:

PN = *Pasaran* day in year-n

u = Today's *pasaran* day

n = Year-n

s = Year today

p = Addition to day

k = Number of leap years

t = Days in a year (365 days)

An example of determining the date of birth ceremonial and *pasaran* day in year-n is the following. A person was born on Thursday, 17 August 1945. His birth ceremonial in the year 2017 is on:

Q = t (mod 7)
= 365 (mod 7)
= 1

HN = m - [{n-s) x q} + k] mod 7
= Thursday - [{(2017-1945) x 1} + 18] mod 7
= Thursday - [{72 x 1} + 18] mod 7
= Thursday - [72 + 18] mod 7
= Thursday - [90] mod 7
= Thursday - 6 days
= Friday

Meanwhile, his *pasaran* day is:

P = t (mod 5) = 365 (mod 5) = 0

PN = u - [{(n-s) x p} + k] mod 5
= Wage - [{(2017-1945) x 0} + 18] mod 5
= Wage - [{72 x 0} + 18] mod 5
= Wage - [18] mod 5
= Wage - 3 days
= Legi

Therefore, from the calculation above, it can be concluded that the *neptu* day date for a person who was born on 17 August 1945 would be on Friday *Legi*.

2. Mathematical modelling in determining the day of funerary ceremony using the death day of the deceased one

This study reveals that in the culture of Yogyakarta, families mourn the deceased 7, 40, 100, and 100 after the person died (Suminah, 2017; Pariyem, 2017). This is to memorize the family of one family members' death, so they can pray for the deceased one. Determining the day of funerary ceremony uses mathematical modeling involving modulo 7 for the 7-day-of-the-week and modulo 5 for the *pasaran* day of the deceased one. The details are as follows.

a. Mathematical modeling on determining the day of funerary ceremony

On calculating the day of the funerary ceremony, it involves mathematical modeling using Modulo 7. It is due to the number of days in a week being seven, and so the days in year-n are divided by seven and resulted in the remainder. If it is divisible by 7, and then it has the remainder seven. Then the remainder is subtracted by one, in which we don't take deceased day into account. It resulted in the number of days needed to be added to the day of death in the year-n. The detailed description is in Table 6.

Table 6. Model of Funerary Day Calculation

The Mourn Day	Calculation of Its Value	Value of the Day	Addition to Day
3	3 (mod 7) = 3	3	3 -1 = 2 means +2 days
7	7 (mod 7) = 0	7	7 -1 = 6 means +6 days
40	40 (mod 7) = 5	5	5 -1 = 4 means +4 days
100	100 (mod 7) = 2	2	2 -1 = 1 means +1 day
1000	1000 (mod 7) = 6	6	6 -1 = 5 means +5 days

Based on the explanation from the mathematical modeling in Table 6, it concludes that:

Addition to day = Mourn day (mod 7)-1

Funerary day ceremony = Day of death + Addition to day or it can be written as:

$$a = b \text{ (mod 7)-1}$$
$$H = c + a$$

Information:

H = Funerary day ceremony

a = Addition to day

b = Mourn day in n by n = 3, 7, 40, 100, and 1000

c = Day of death

b. Mathematical modeling in determining *pasaran* day of a death person

In predicting the *pasaran* day of the deceased one, we apply mathematical modeling integrating modulo 5. Therefore, for those days in a year n which is divisible by five, and it has remainder five (Utami, Sayuti, & Jailani, 2019). The remaining is then subtracted by one because we don't take the deceased day into account. Then, it results in the number of days to be added to the *pasaran* day of the deceased one. The detailed explanation is in Table 7.

Table 7. Model for Calculating the *Pasaran* Day of the Deceased One

The Mourn Day	**The Value of the *Pasaran* Day**	**Value of the Day**	**Number of Addition to *Pasaran* Days**
3	3 (mod 5) = 3	3	3 - 1 = 2 means, +2 *pasaran* day
7	7 (mod 5) = 7	7	7 - 1 = 6 means, +7 *pasaran* day
40	40 (mod 5) = 0	5	5 - 1 = 4 means, +4 *pasaran* day
100	100 (mod 5) = 0	5	5 - 1 = 4 means, +4 *pasaran* day
1000	1000 (mod 5) = 0	5	5 - 1 = 4 means, +4 *pasaran* day

Based on the explanation from the mathematical modeling in Table 7, it concludes that:

Addition to the *pasaran* day = The Mourn day (mod 5) -1

The ceremonial *pasaran* day = Deceased day + addition to *pasaran* day

or it can be written as:

$$D = b \text{ (mod 7)-1}$$
$$P = c + d$$

Information:

P = The *pasaran* day of the deceased one in year-n

d = Addition to *pasaran* days

b = The-n mourn day n = 3, 7, 40, 100, and 1000

c = The actual *pasaran* day of the deceased one

It is an example to calculate the mourning celebration and its *pasaran* day for a person who died on Friday *Legi*. It is detailed in Table 8.

Table 8. An Example of the Mourn Day of the Death Day

The-n Mourn Day	The Death Day	Addition to Day	The Mourn Day
3	Friday	+ 2 days	Sunday
7	Friday	+ 6 days	Thursday
40	Friday	+ 4 days	Tuesday
100	Friday	+ 1 days	Saturday
1000	Friday	+ 5 days	Wednesday

Meanwhile, the day for the ceremonial is detailed in Table 9.

Table 9. An Example of the Mourn Day of the *Pasaran* Day

The-n Mourn Day	The *Pasaran* day	Addition to Day	The *Pasaran* Day for the Funerary Ceremony
3	*Legi*	+ 2 days	*Pon*
7	*Legi*	+ 1 days	*Pahing*
40	*Legi*	+ 4 days	*Kliwon*
100	*Legi*	+ 4 days	*Kliwon*
1000	*Legi*	+ 4 days	*Kliwon*

Therefore, a person who died in Friday *Legi* will have funerary ceremony day in Table 10.

Table 10. Result for *Pasaran* Day of Funerary Ceremony

The-n Mourn Day	The Day of Funerary Ceremony	The *Pasaran* Day for the Funerary Ceremony
3	Friday	*Pon*
7	Thursday	*Pahing*
40	Tuesday	*Kliwon*
100	Saturday	*Kliwon*
1000	Wednesday	*Kliwon*

The results of the mathematical modeling exploration of Yogyakarta's culture *pranatamangsa* have added references and knowledge concerning the use of cultural contexts which are potential as starting points in learning mathematics. In Hawaii, there is a lunar calendar system namely Hawaiian moon calendar similar to the lunar calendar-*pranatamangsa* in Yogyakarta, Indonesia. It turns out to be used well for learning mathematics based on past, present, and future mathematics to prepare leaders who have wisdom about their ancestors' culture in using mathematical modeling (Kaomea, 2019). Furthermore, Utami, Sayuti, and Jailani (2019) investigated the Javanese *pasaran*-fortune day (primbon), Sugianto, Abdullah, and Widodo (2019) explored number patterns, 2D figures, and number operations in Reog Ponorogo culture, and Kemaro island legend can be used to teach statistics (Lestariningsih, Putri, & Darmawijoyo, 2012). In addition, several games have been explored as a starting point in learning number operations using *bermain satu rumah* traditional game (Nasrullah & Zulkardi, 2011), social arithmetic using *kubuk manuk* games (Risdiyanti, Prahmana, & Shahrill, 2019), and Gundu for learning linear measurement (Wijaya, Doorman, & Keijzer, 2011).

Integrating Ethnomathematics can be helpful to make mathematics relevant, meaningful to students, and foster their performances. If we look into the case of the low performance on critical thinking and reasoning from the Program for International Student Assessment (PISA), it might be affected by teachers who have not integrated students' social and cultural life in learning mathematics (Muhtadi, Sukirwan, Warsito, & Prahmana, 2017). Teachers deliver what is written on the textbooks without igniting interactive dialogue to enhance students' critical reasoning and communicate different ideas (Stacey, 2011; Arisetyawan, Suryadi, Herman, & Rahmat, 2014). This led students to memorize formulas without knowing its meaning and not being reflective of mathematics they learn at schools (Nurhasanah, Kusuma & Sabandar, 2017; Risdiyanti & Prahmana, 2020). Therefore, to solve this problem, we need to relate mathematics and social-culture contexts close to students by exploring cultural backgrounds to be used in mathematics learning.

Ethnomathematics studies have helped teachers and students to understand mathematics in contexts of ideas, ways, techniques used in real life to enhance students' interest, understanding, and creativity (D'Ambrosio, 1999; Freudenthal, 2006; D'Ambrosio, 2007). This study is in line with the aim of mathematics education in Indonesia, such as to make students understand mathematical concepts and their relationship. The reason is to make mathematics generalization-proof-ideas, explain mathematical ideas, and solve real-life problems mathematically. Mathematics exists because of the need for humans to respond to the problems and or environment and solve problems, as it is crucial to infuse social values through ethnomathematics so that students can reflect on it for their lives (D'Ambrosio & D'Ambrosio, 2013). Lastly, mathematics education in Indonesia needs to contextualize mathematics in a social environment and culture.

CONCLUSION

Yogyakarta's culture includes mathematical modeling to determine seasons in the *pranatamangsa* system and the birth-death ceremonial. In determining the seasons, people of Yogyakarta use a one-to-ten season system, which is essential for them to, especially for farmers and fishermen. They predict which fish they will catch and tools to be used by studying natural phenomena.

Meanwhile, the farmers use *pranatamangsa* to determine the crops they will plant, seeding time, and crop time.

Besides, in Yogyakarta's culture, people mourn the death on days 3, day 7, day 40, day 100, and day 1000 to pray for the deceased one. They also celebrate their birthday by using *neptu* days. The determination of the date of birth-death ceremonial uses mathematical modeling integrating modulo 5 and modulo 7. Lastly, these rituals still exist in people of Yogyakarta who live in villages. This study has shown a rich culture containing mathematical modelling which are potential to be used in learning mathematics topics such as patterns, modulo, and number sense. It is expanded to be a reference for educators in Yogyakarta to improve students' understanding and relation of mathematics and their culture and lives.

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Ethnomathematics: Pranatamangsa system and the birth-death ceremonial in yogyakarta (Article)

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Abstract

Mathematics exists as rooted in human ideas, ways, and techniques to respond to their environments. Along with its development, mathematics has been taught through formal education or schooling in the flat- not flexible ways and far from students' social and cultural lives. Indonesia is rich with culture, including the Special Region of Yogyakarta (DIY). It is called a city of culture. Educators are not yet aware of this richness in the learning process to integrate it as the starting point. It is hard to find in mathematics textbooks in Indonesia, which put cultural context as starting points. Therefore, this study aims to explore Yogyakarta's culture in terms of contexts used in mathematics learning. It is an ethnography study. Furthermore, the data was collected through literature artifacts, field observation, and interviews with resource persons who understand the seasons, system, and calculation of birth and death days. It is to clarify the researcher's understanding of the literature. This study showed that Yogyakarta's people use mathematical modeling to determine the seasons' system and funerary dates. These models have the potential to be used as a starting point in learning mathematics.

Author keywords

Birth and death dates | Ethnomodeling | Mathematical modelling | Seasons system | Yogyakarta culture

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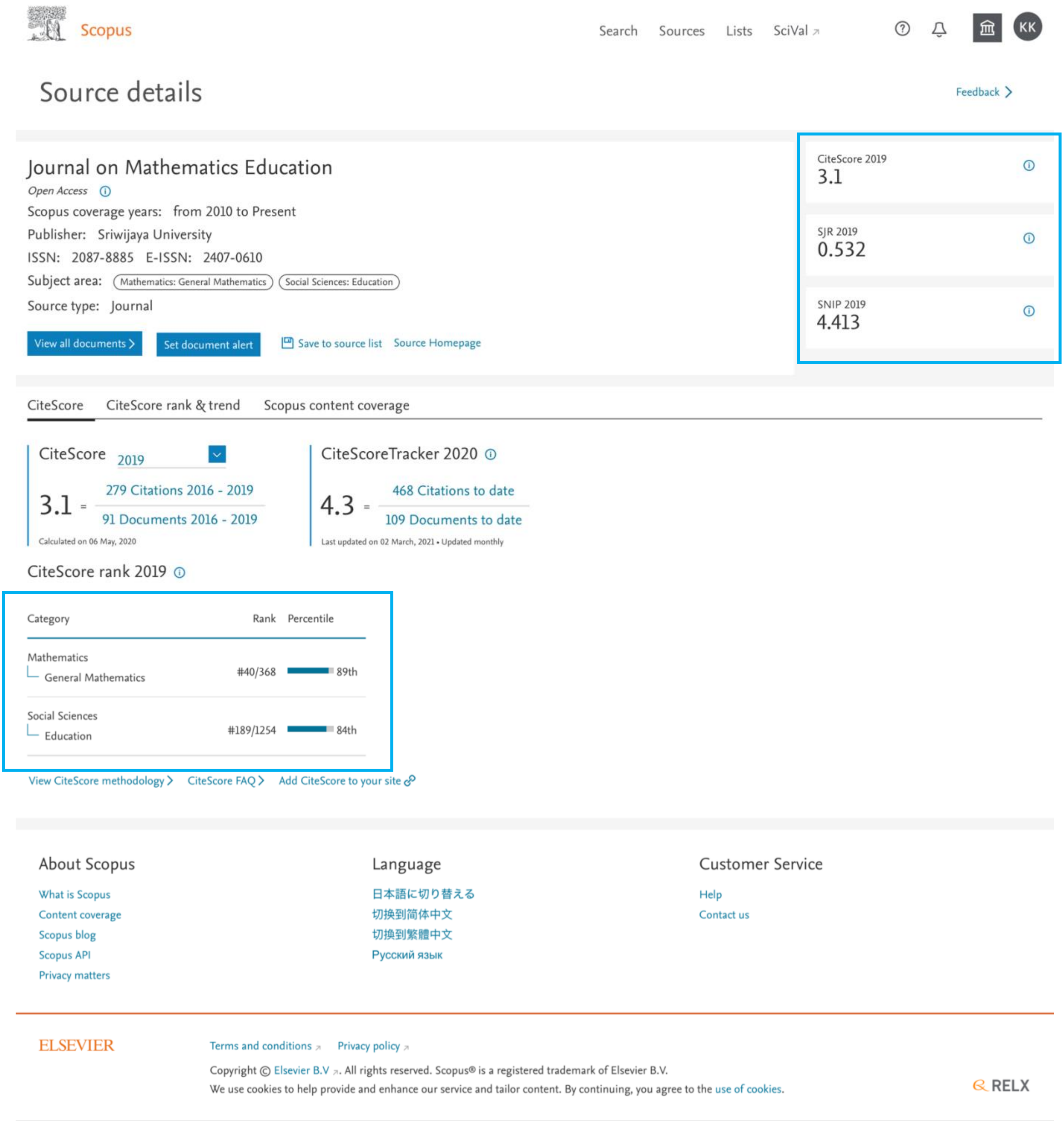

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