

## Mathematics and the *Dan* Culture<sup>1</sup>

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### Abstract

The author was a Fulbright Professor of Mathematics in Monrovia, Liberia, when he had the opportunity to travel upcountry and talk with informants from the villages of Dayala, Graie, Ziah, Zontuo, Zuolay, and Zwatuo, and from the towns of Karnplay, Tappita, and Towehtown. From market women and *zo* (powerful female medicine makers) to village elders and chiefs, the *Dan* tribal members showed tremendous pride in their heritage and an openness to discuss most aspects of their culture including how mathematical concepts are expressed in their language and embedded in their activities. It is unclear how this pride and openness have been affected by the recent civil war in Liberia in which half the *Dan* population were displaced and over ten percent were killed.

### Introduction

This study provides an extensive, but far from complete, description of mathematical ideas and practices expressed in *Dan*, a tribal language (and culture and people) of the central Liberian hinterland. From measuring rice to constructing round huts, from games of chance to telling time, mathematics is embedded in their day-to-day activities. A child's counting song gives an illustrative example:

*Doh lay? Doh yah loh weeay ...*

Where's one?

One has gone to Monrovia.

Where's two?

Two ran into one, and one has gone to Monrovia.

Where's three?

Three ran into two, two ran into one, and one has gone to Monrovia.

Language is critical as *Dan* is non-written, all measurements are descriptive, and logical connectives have a distinct complex structure.

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## The *Dan* People in Liberia

The *Dan*, one of the largest tribes in the West African Liberian rain forest, have a vital, tonal language which is the repository of much of their culture including oral literature, law, song, history, and traditional stories. Three major studies (Griffes, 1959; Doneux, 1968; and Bolli, 1976) of this language have dealt with pronunciation, basic grammar and some elementary vocabulary.

According to legend, *Ye* and *Ye* were the parents of *Abi*; *Abi* in turn fathered *Za*; and finally *Za* and the “cat-woman” had three children, one of whom, the wise man *Ma*, was the father of the *Dan* tribe (also called the *Gio* by early missionaries). The *Dan* are known for their old and elaborate system of masks – forest spirits reveal themselves and express their wishes through tribal members dancing with specific masks. (This author was fortunate to have occasion to observe the tall mask spirits on concealed stilts, three times a man’s height, dancing about with their preposterous long legs bending, now this way, now that. They sat on roof tops to rest! When walking, they leaned impossibly backwards, catching themselves instead of falling. One approached a compound wall, sat on it, lifted one leg at a time to the other side, and resumed his stroll. However, this author also was severely warned to stay inside one night when the scary-serious mask spirits were about. It was related that some of these mask spirits had even mastered space and time so as to appear simultaneously in places far apart. Based in our Western oriented schooling, this is something that we Westerners do not believe is possible. In this perspective, deep in the Liberian rain forest, space and time appeared to obey laws different from those set down by Western scientists.)



Figure 1: *Dan* masks (photos by M. Sternstein)

Village life centers around the palaver hut, in which are found drums and hammocks, hunting trophies, and games to be played; where arguments are settled and court cases are tried; and where dancing on moonlit nights is a wondrous sight to behold. The palaver hut is an open structure with low walls imbedded with posts to support its thatch roof.

Perhaps just as important is the medicine hut, a clay structure perhaps ten feet in diameter and four feet high with thatch roof. This is the first structure erected in a new town. In olden days an ornamented young woman would be buried alive on the spot, but this ritual has long since been replaced by the sacrifice of a white chicken. Special medicines, unique for each village, are kept in the hut to bring prosperity.

*Dan* houses are circular mud and stick structures with two doors and cone shaped thatch roofs extending far over the walls. The earth floor is leveled, pounded hard, and rubbed with charred

cow dung for a smooth finish. The inner walls are usually decorated with murals. This architectural tradition is in marked contrast with the two major neighboring tribes: the *Kpelle* typically have square huts whose outer walls are decorated with drawings, while the *Bassa* have rectangular huts with porches in front. (While the tribes may be neighbors, their architecture, as well as language and culture, have very little in common!) In all three cases, these classical hut types are more and more giving way to rectangular houses of mud blocks with zinc roofs.

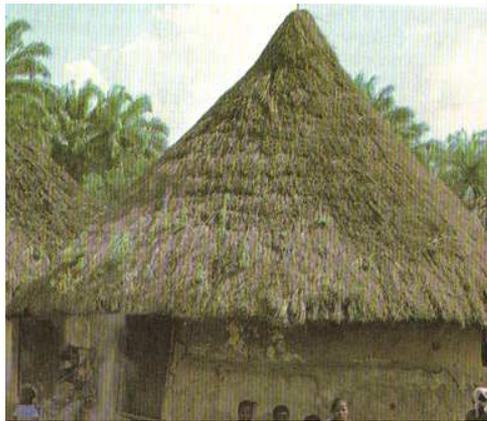


Figure 2: Dan traditional hut (photo by M. Pineiro)

While life in a *Dan* village is often a struggle against disease (especially malaria and intestinal parasites) and encroachment from the outside (Western) world, food is usually not the serious problem that one finds outside the rain forest and closer to the Sahara. (Stories of starvation were common, however, during the protracted civil war of the 1990s.) The men hunt and set traps while the women fish. Rice is the staple with many expressions used for measuring quantities of rice. The men cut and burn the bush, while the women plant and care for the rice crop. Rice harvesting is a shared responsibility. Rice is supplemented by cassava, plantain, sweet potato, and a variety of yams and fruits. The basic rice meal is served with “soup,” that is, greens, meat or fish fried in palm oil and spiced with such condiments as eggplant, very hot pepper, okra, bitter balls (size of large cherry tomatoes, from eggplant family but slightly bitter) and tomato (*gboumeh ahzo* – “a rich person’s bitter ball”).

### **The Mathematical Ideas and Practices of the Dan People**

Here we look into the *Dan* culture and mathematics, where mathematics is broadly interpreted to include arithmetic, measurement (length, area, volume, and time), geometry, logic, and games (Ascher, 1991). The premise is that what ideas can be expressed, and in what manner these concepts are expressed, are an important step in the study of a culture. As Lipka (1994) points out, the cultural and linguistic ways a society makes sense of the world includes the worldview upon which their mathematics is formulated. Barton (2004) too stresses the close relationship between language and mathematics.

Since the *Dan* have an oral (non-written) language, all *Dan* words below are written using the International Phonetic Alphabet (International Phonetic Association, 2005). The effect on

mathematics of having a non-written language is an open question crying out for research.

## ARITHMETIC

As can be observed below, the *Dan* number system is base 10 with sub-base 5 (note how the numbers 6 through 9 incorporate the numbers 1 through 4).

1	<i>do</i>
2	<i>peetε</i>
3	<i>yaaka</i>
4	<i>yiisiε</i>
5	<i>sɔɔlu</i>
6	<i>srɔado</i> ( <i>sɔ</i> letters from <i>sɔɔlu</i> and a <i>do</i> ending)
7	<i>srɔapeetε</i> ( <i>sɔ</i> letters from <i>sɔɔlu</i> and a <i>peetε</i> ending)
8	<i>srɔayaaka</i> ( <i>sɔ</i> letters from <i>sɔɔlu</i> and a <i>yaaka</i> ending)
9	<i>srɔayiisiε</i> ( <i>sɔ</i> letters from <i>sɔɔlu</i> and a <i>yiisiε</i> ending)
10	<i>gɔɔdo</i>
11	<i>gɔɔdo ga do</i>
12	<i>gɔɔdo ga peetε</i>
20	<i>gɔɔpeetε</i>
25	<i>gɔɔpeetε ga sɔɔlu</i>
87	<i>gɔɔsrɔayaaka ga srɔapeetε</i>
100	<i>kəndo</i>
300	<i>kənyaaka</i>
1000	<i>waado</i>
40,000	<i>waagɔɔyiisiε</i>

While there are words *wεa* (empty), *pəgbεε* (nothing), and *fee* (an insult when referred to a person) which all in some ways can represent the number 0, there is no number 0 in *Dan* in the same way there are counting numbers 1, 2, 3, ... (The author was told by village informants that if he gave away all his fish, he would have *nothing*; and that the expression *nothing* fish or *empty* fish did not make sense.)

Basic operations are rendered as in the following examples.

$1 + 1 = 2$	<i>do ya da do pieε, e tɔɔ peetε</i> literally “1 put with 1, it is named 2.”
$2 - 1 = 1$	<i>do ya go peetε pieε, e tɔɔ do</i> literally “1 taken out of 2, it is named 1.”
$3 \times 2 = 6$	<i>peetε gɔɔɔu yaaka, e tɔɔ srɔado</i> literally “3 different 2’s put together, it is named 6.”

$6 \div 2 = 3$       *srɔado gygru kou peetɛ, e tɔɔ yaaka*  
literally “6 split up into 2, it is named 3.”

Subtraction of a larger number from a smaller, and division with a nonzero remainder are not allowed.

$1 - 2 = ?$       *peetɛ ya go do pieɛ, yaakə*  
literally “2 taken out of 1, it can’t happen.”  
(As village informants explained to the author, if you have five fishes you can sell three of them, but if you have only one fish, you can’t offer to sell two fishes!)

$3 \div 2 = ?$       *yaaka gygru kou peetɛ, yaa lo mɔ*  
literally “3 split up into 2, it’s not possible.”

Even though the expression “ $3 \div 2$ ” is not proper *Dan*, fractions can be informally described using the word *pɛ* meaning “piece.”

$1/2$	<i>pədo pɛ peetɛ</i>	“one thing split into two pieces”
$1/3$	<i>pədo pɛ yaaka</i>	“one thing split into three pieces”
$2/3$	<i>pə peetɛ pɛ yaaka</i>	“two things split into three pieces”

## MEASUREMENT

All measurements of length, area, volume, and time are descriptive.

Length (the “string” and “rope” measurements below are used in construction, while the three “walking” measurements are used for distances between towns.)

<i>kɔnəpo</i>	“stretch one’s fingers” – distance from tip of thumb to tip of center finger when stretching.
<i>gɛsɬdo</i>	“lift a foot” – length of a man’s foot.
<i>dua gɔdo</i>	“ax handle” – distance from finger tip to elbow.
<i>gɛpo</i>	“stretch one’s feet” – length of a foot step.
<i>gbie po</i>	“stretch one’s arms” – distance between finger tips of outstretched arms.
<i>dθn ga</i>	“thread from palm leaf” – refers to a string measurement where a fixed length to be reused is marked on a string.
<i>bɬa ga</i>	“rope from a vine” – refers to a rope measurement.

<i>yi do ta</i>	“one day’s walk” – the distance that can be walked from sunup to sundown.
<i>lɔɔ gɔ do ta</i>	“walking between market days” – the distance that can be walked in one week.
<i>su do ta</i>	“one moon’s walk” – the distance that can be walked from one full moon to another.

### Area

<i>gɔɔ fiasɰ a blɰɰ</i>	“lazy man’s farm” – a small farm (As village informants explained to the author, it is unclear whether a farm encompassing such an area will produce enough rice even for a nuclear family, let alone an extended family.)
<i>blɰɰ ba dɔ a kɔpɛa doba ba mɛ wo ma a kɔpɛa bazɛa la</i>	“a farm where someone on one side can’t hear someone on the other side” – a large farm.
<i>pθθ ba dɔ a kɔpɛa doba ba mɛ ye a kɔpɛa bazɛa la</i>	“a town where someone on one side can’t see someone on the other side” – a large town.

### Volume

<i>nəa gbɔ nə</i>	child’s clay pot (holds about 1 pound of rice)
<i>kɔupə</i>	clay bowl for hand washing (holds about 2 pounds of rice)
<i>bɛan</i>	clay bowl for eating (holds about 4 pounds of rice)
<i>wakə bɛan</i>	large bowl for feasting (holds about 10 pounds of rice)
<i>pə dan too nə</i>	small basket used for measuring
<i>voə</i>	large measuring basket
<i>kpuu</i>	vase shaped basket
<i>yikɔɔ</i>	medium size calabash

The market women make use of all these measurements, and have the amazing ability to look at a large pile of rice and instantly and quite accurately give its size in terms of any of the above

measurement scales. This was observed by the author, and has also been commented upon by Gay and Cole (1967).

### Time

Time of day is determined by the position of the sun or by the hour a specific event happens.

<i>nla pɛla</i>	“sun is breaking” – about 6 AM
<i>du nəbɔna</i>	“young cow jumping time” – about 9 AM (as village informants explained to the author, at this time of the morning, calves are “frisky.”)
<i>nla ya dɔmɛ tu zinɛ</i>	“sun has reached top of one’s head” – noon
<i>nla ya tə</i>	“sun is tilted” – about 1:30 PM
<i>nla ya dɔmɛ to gbɛa la</i>	“sun is on your ear” – about 3 PM
<i>nla ya sonya</i>	“sun is about to fall” – about 4:30 PM
<i>kuɔdɛa nla</i>	“chimpanzees are fooled by the sun” – strong sunlight just before sunset
<i>nla ya da yoobaa</i>	“sun falls in the sea” – about 6 PM
<i>bi ya mə</i>	“it is dark” – evening

A day, *yi*, begins with sunrise and ends at sunset. The weekly unit is the market, so while *lɔyi* means “market day,” *lɔ* by itself can informally mean “week.” The word for “month” is *su* which literally means “moon.” However, while months are very loosely associated with the length of a cycle of the moon, they are more accurately recognized by weather and agriculture happenings, and thus can vary in length from year to year.

<i>luɛsu biɛzə</i>	“first dew month”
<i>luɛsu yeapie</i>	“dew month that steps behind”
<i>luɛsu kaala</i>	“last dew month”
<i>glevaani</i>	“things burn quickly” – time to burn bush to make farm
<i>zəzə</i>	“can’t sit down” – busy month on farm
<i>duo</i>	“plenty” – lose or gain plenty depending on success of farm

<i>plepoo</i>	“too wet”
<i>klabɔnpa</i>	“hoe is filled” – rain soaked mud sticks to the hoe
<i>dθneizɔɔ</i>	“worry” – about neighbor who had not made farm
<i>dɔu</i>	“big happening” – heavy rains, lightening, and thunder
<i>supuu</i>	“bright moon” – cloudless sky, dry season is coming
<i>nɛɛsu</i>	“cold month”

Beginnings and endings of years are not particularly noted, and years are not usually recognized by numbers, however one might refer to the time of a noteworthy event, for example, *wa kpɔ kwɛ Tama ya bɛ gɥ* – “He was born the year President Tubman died.”

The positions of several constellations are also followed.

<i>zθθgru</i>	“flock of little pepper birds” – Pleiades
<i>dua gɔ boagɥ</i>	“remove an ax handle” – Orion
<i>gɛ sagli</i>	Ursa Major
<i>yenegruzengru</i>	“red ants and pepper birds” – combination of the Pleiades and the three stars in Orion near his belt (farm cutting must begin when this is showing far in the east).

## GEOMETRY

<i>pθ ga yaaka zθ</i>	“thing with 3 corners” – a triangle
<i>pθ ga yiisiɛ zθ</i>	“thing with 4 corners” – a square (the author also heard this used with reference to rectangles which were not squares, but never in reference to more general quadrilaterals.)
<i>pθ niɛ gy sy zθ</i>	“thing which goes around” – any kind of rounded figure
<i>gblɔugba</i>	“box” – a rectangular solid
<i>pθ lθθlθ</i>	“thing which is round” – a sphere (there do not appear to be expressions for 3-dimensional geometric figures other than the “box” and the sphere.)

Geometric principles are used in building construction. The placement of the outer wall of a circular house is determined by driving a center stake, tying a vine rope (*b~~tu~~ ga*) from this to a movable stick, and then holding the vine taut as the movable stick traces a circle on the ground. A stake is corrected to vertical by swinging a surrounding circle, taking three equal lengths of vine, stretching from the circle to a point on the stake, and finding a point such that the three vines are all taut. The stake is then vertical. (This remarkable procedure was witnessed by the author, and, after some head scratching, was mathematically confirmed. Seen in this context, the bridge between academic mathematics and their mathematical practice, in this one particular example, was in geometrically achieving a vertical line. In doing so, basically, triangle ABP is isosceles and thus the vertical plane which is perpendicular to the segment AB and passes through the midpoint of AB will also pass through P. Similarly, triangle ACP is isosceles and thus the vertical plane which is perpendicular to the segment AC and passes through the midpoint of AC will also pass through P. These two vertical planes meet in a vertical line containing P and which intersects the ground at a point equidistant from A, B, and C, that is, at the center of the circle.) A rigorous geometric proof can be found in a solid geometry text such as: (Welchons, 1965).

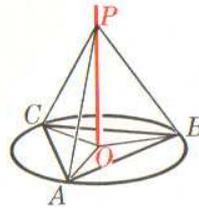


Figure 3: Center stake *OP* with equal lengths of vine *AP*, *BP*, and *CP*.

## LOGIC

In *Dan* the negation of a sentence is easily constructed.

<i>e lo pθθ</i>	“He went to town.”
<i>yaa lo pθθ</i>	“He didn’t go to town.”

The possibilities and ease of constructing binary sentences corresponding to logical connectives are illustrated in the following:

### Conjunction

<i>e tabola, e takθla</i>	“He is singing, he is dancing.”
(There is no <i>Dan</i> word for “and” in translating the English sentence: “He is singing, and he is dancing.”)	

<i>gεya, e ya kpa gθε, yεnε</i>	“The pot, she cooks rice in, this is it.”
(There is no <i>Dan</i> word for “which” in translating the English sentence: “This is the pot which she cooks rice in.”)	

<i>nla e bya, sie e mθm pie</i>	“Sun is shining, the heat is upon me.”
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(There is no *Dan* word for “so” in translating the English sentence: “It is sunny, so I am hot.”)

### Disjunction

*e lo nu ya ka, yaa kɔɔɛ, e lo nu bee ka* “He will bring rice, if not he will bring cassava.”

(There is no *Dan* word for “or” in translating the English sentence: “He will bring rice, or he will bring cassava.”)

*yibukaɛ e lo lo pθθ, yibukaɛ ya lo lo pθθ* “Maybe he will go to town, maybe he won’t go to town.”

(There is no *Dan* word for “or” in translating the English sentence: “He will go to town, or he won’t go to town.”)

### Implication

*aye ya yɔkθ biɛ ekɛɛ wo la kɔɔ nu* “If he works hard, then they will pay him.”

(The implication “If ... then ...” can be directly translated into *Dan* as “*aye ... ekɛɛ*”)

However, there is no *Dan* expression for the English double equivalence “if and only if.”)

In a study of the Kpelle of Liberia (Gay & Cole, 1967) it was noted that the Kpelle have no simple way of creating conjunctive statements, a less ambiguous expression of disjunction than English, and, like the *Dan*, an easy expression of direct implication, but no expression for double equivalence. However, as Zepp (1983) points out, experimental testing through problem solving may well give more accurate conclusions about the meaning of logical statements than does reliance on direct translation. (Such psycholinguistic research on the *Dan* should be an important area for future research.)

## **GAMES**

In the *Dan* culture are found a variety of games many of which illustrate arithmetical, geometrical, or probabilistic principles.

The board game (*ma*) with 2 rows of 6 cup-like holes. This old game, one of the oldest in the world, also going by the names *mankala*, *oware*, and *wari*, has a clear arithmetical counting foundation. The author was impressed with the speed at which the players made their moves, and that the *Dan* players never had to physically count the number of pebbles in a hole, but rather mentally kept track of the numbers. (The author, who considers himself a good game player, was crushed in every game played.)



Figure 4: Ma Board

The gambling game (*kpoo*) where cowrie shells are tossed like dice. (The probability of landing with a particular side up was unclear to the author, however while it did not appear to be 0.5, it did appear that the game players had a good understanding of what the probability was, and they were not particularly interested in sharing their knowledge!)



Figure 5: Cowrie Shells

Cat's cradle games with string (*denga*) made from palm leaves.

Paper folding games using banana, palm, mango, and cassava leaves.

Pebble manipulation games – the hand is quicker than the eye. (The pebble was hidden under one of three large cowrie shells.)

The spinning top game (*si*) where various players simultaneously spin tops made from palm nuts and try to knock opponents' tops out of a circle.

## THE ROLE OF THE UNIVERSITY IN AFRICA

While we will barely touch this topic, some points should be noted as they bear on studies such as this. First, African universities are among the oldest educational institutions world wide. For example, Al Akhawayn founded in the ninth century in Fez, Morocco, and Alazhar founded in the tenth century in Egypt are still in existence. Liberia College (later the University of Liberia) opened in 1862. According to Sherman (1990), a former president of the University of Liberia, today's African universities, in addition to the pursuit of knowledge shared by all universities, should "bring vibrancy to the traditional environment and pride in cultural heritage." N'Daw (1969) also spoke of the African university's challenge to create new ideas by working from the strength of the culture. Finally, a workshop organized by the AAU (Association of African Universities) in Accra, Ghana, in 1972, concluded that the African university must be accountable to the vast majority of people who live in rural areas (Yesufu, 1973). All these authors strongly suggest that studies such as this on *Dan* mathematics should be encouraged,

supported, and find a home in African universities.

An important undertaking by African universities would be in the area of curriculum development for teaching primary grades in native languages. In particular, in Liberia there has been a whole generation of child-soldiers who have received absolutely no education other than how to kill. This problem is especially serious in Nimba County, home of most of the native *Dan* speakers, and where much of the civil war was fought. A university developed, “Learning-from-Language” approach as proposed by Denny (1980) would seem promising. This technique involves working with a team consisting of an applied linguist and a math teacher together with native *Dan* speakers to examine each area of the mathematics curriculum for patterns and meanings of the *Dan* words. The goal would be curriculum in which a child’s learning of mathematical concepts flows smoothly out of his preschool *Dan* education.

## CONCLUSION

As in many non-Western cultures, *Dan* has no word for *mathematics*, however mathematics is seen to be embedded in day-to-day activities. While this paper provides an extensive description of expressions, ideas, and practices of mathematics in this old culture, it also raises a number of issues for further study. One important future study is what consequence, if any, is there on mathematics where the means of expression is a non-written language. A second future study regards experimental testing through problem solving to give more accurate conclusions about the meaning of logical statements in *Dan* rather than reliance on direct translation. And a further necessary study is the effect on old, traditional, indigenous traditions (including uses of mathematics) when a devastating civil war displaces half the population, literally scattering refugees around the world.

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