Spreadsheets in Education (eJSiE)

Volume 8 | Issue 1 Article 6

3-28-2015

Divination: Using Excel to explore ethnomathematics

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Abstract
This paper presents the way Microsoft Excel is used as a tool to explore properties of the sikidy divination system used in Madagascar. This is an example of how topics of ethnomathematics can be investigated using a technological tool. We simulated the construction of the mother-sikidy and used tools from Excel to present its properties graphically. We considered a generalization of the sikidy divination system and realized that some properties still hold. Using the technology provides opportunities to persevere in solving mathematical problems.

Keywords
ethnomathematics, divination, parity, sikidy

1. Introduction

This paper is the result of the work of one undergraduate student (second author) in the research experience of her mathematics program. Our program has developed a sequence of courses where students experience how mathematicians do mathematics, use technology as an exploration tool for research, and have opportunity to communicate their results in professional avenues. Brown & Yürekli [1] present a detailed description of this component of our undergraduate program.

Ethnomathematics studies the relationships between mathematics and cultures. Different cultures use non-traditional mathematical ideas, which are embedded in their everyday life. D'Ambrosio introduced the term ethnomathematics in order to refer to these ideas in 1984 [2]. According to Asher [3], ethnomathematics is the study of mathematical ideas of people in small-scale traditional cultures and can be presented in any activity where the main purpose is not to do mathematics. Cultures derive their own forms of ethnomathematics depending on their practices and necessities. It can include cooking, architecture, leisure activities, agriculture, and more. Many cultures have developed their own ways of counting and measuring and their own systems for making quantitative comparisons and even developing arithmetic [4].

Ascher [5] studied the mathematical ideas embedded in a form of divination practiced in Madagascar. As explained in her article, divination is a decision making process which utilizes a randomized mechanism. The decisions sometimes involve the determination of the cause of some event or whether to carry out some future action. In general, divination is a shared systematic approach to knowledge using formal or ritualistic elements. Divination systems are considered to be sciences by some scholars [6].

Ascher examined the particular system of divination called Sikidy that has a long history and it is still practiced and of great significance in Madagascar. This paper will explore the mathematical properties of Sikidy by using Microsoft Excel, which will help developing graphical representations of the properties. This will enable us to extend the process used in Sikidy and to provide an opportunity to explore which properties still hold.

2. Sikidy Divination System

A guide called "ombiasy" performs Sikidy. The ombiasy has knowledge of formal divining practices. During Sikidy divination process, he combines the divining materials and interprets the outcomes. At each stage, he asks questions and discusses the interpretations with the client. The process continues until the client realizes her/his problems are resolved. Malagasy is the national language of Madagascar. In Malagasy culture, the place of divination is important. The ombiasy may face various questions such as how the weather will be in a trip, planting, or ceremonial moving of the family tomb.

The practice of Sikidy falls within the mathematical concept of symbolic logic and also includes concepts of parity and parity checking. In Sikidy, the classes in the two-valued logic are odd and even; the symbols for them one seed, represented by o, and two seeds, represented by oo. The basic operation combining two or more of these symbols follows the results presented in Figure 1 which corresponds to the addition table in modulo 2.

+	o	oo
o	oo	o
oo	o	oo

Figure 1: Addition table for combining seeds

The ombiasy has a bag of enough dried seeds gathered from a fano tree for his subsequent use during the divination process. The ombiasy takes a fistful of seeds from his bag and randomly lumped into for piles. Then, he reduces the pile to one or two by deleting two seeds at a time. The four remainders become the entries in the last column $\boldsymbol{C_1}$ of a four by four matrix. The entire process, beginning with another selection of a fistful of seeds from the bag, is then repeated three more times each of which forms the remaining columns $\boldsymbol{C_2}$, $\boldsymbol{C_3}$, and $\boldsymbol{C_4}$ of the four by four matrix. An example of such a matrix with random entries and column labels is presented in Figure 2. This randomly generated initial four by four matrix is called the mother-sikidy, and each column and each row has a particular name in the divination process.

$\boldsymbol{C_4}$	$\boldsymbol{C_3}$	$\boldsymbol{C_2}$	$\boldsymbol{C_1}$
o	o	o	oo
o	o	oo	oo
oo	oo	oo	o
o	o	o	o

Figure 2: An example of a mother-sikidy

After the first four columns are created randomly, the next four are created using the mother-sikidy. $\boldsymbol{C_5}$ is the top row reading from right to left. Continuing down, $\boldsymbol{C_6}$, $\boldsymbol{C_7}$, and $\boldsymbol{C_8}$, are created in the same way. Each entry of the matrix can be one seed or two seeds, therefore there are $2^{16} = 65536$ different possible matrices. In order to demonstrate the remaining process, we will label the rows, columns, and entries of the mother sikidy as shown in Figure 3.

Using the mother-sikidy a new four by eight matrix is obtained using combination of the already generated columns. Figure 4 presents the new matrix. The order of the indexes for $\boldsymbol{C}$ reflects the process the ombiasy follows to create the final tableau used for the divination.

C_4	C_3	C_2	C_1	
$a_{1,4}$	$a_{1,3}$	$a_{1,2}$	$a_{1,1}$	C_5
$a_{2,4}$	$a_{2,3}$	$a_{2,2}$	$a_{2,1}$	C_6
$a_{3,4}$	$a_{3,3}$	$a_{3,2}$	$a_{3,1}$	C_7
$a_{4,4}$	$a_{4,3}$	$a_{4,2}$	$a_{4,1}$	C_8

Figure3. The mother-sikidy.

C_9	C_{13}	C_{10}	C_{15}	C_{11}	C_{14}	C_{12}	C_{16}
$e_{1,9}$	$e_{1,13}$	$e_{1,10}$	$e_{1,15}$	$e_{1,11}$	$e_{1,14}$	$e_{1,12}$	$e_{1,16}$
$e_{2,9}$	$e_{2,13}$	$e_{2,10}$	$e_{2,15}$	$e_{2,11}$	$e_{2,14}$	$e_{2,12}$	$e_{2,16}$
$e_{3,9}$	$e_{3,13}$	$e_{3,10}$	$e_{3,15}$	$e_{3,11}$	$e_{3,14}$	$e_{3,12}$	$e_{3,16}$
$e_{4,9}$	$e_{4,13}$	$e_{4,10}$	$e_{4,15}$	$e_{4,11}$	$e_{4,14}$	$e_{4,12}$	$e_{4,16}$

Figure 4. A new matrix from the mother-sikidy

Each new column is created using the ones already created, using the following algorithm,

$$\boldsymbol{C_9}: e_{i,9} = a_{3,i} + a_{4,i};\ \boldsymbol{C_{10}}: e_{i,10} = a_{1,i} + a_{2,i};\ \boldsymbol{C_{11}}: e_{i,11} = a_{i,4} + a_{i,3},\ \boldsymbol{C_{12}}: e_{i,12} = a_{i,2} + a_{i,1}$$

$$\boldsymbol{C_{13}}: e_{i,13} = e_{i,9} + e_{i,10};\ \boldsymbol{C_{14}}: e_{i,14} = e_{i,11} + e_{i,12}$$

$$\boldsymbol{C_{15}}: e_{i,15} = e_{i,13} + e_{i,14}$$

$$\boldsymbol{C_{16}}: e_{i,16} = a_{i,1} + e_{i,15}$$

$$i = 1, 2, 3, 4.$$

Figure 5 shows how $\boldsymbol{C_1}$ through $\boldsymbol{C_8}$ combine to form the other columns visually.

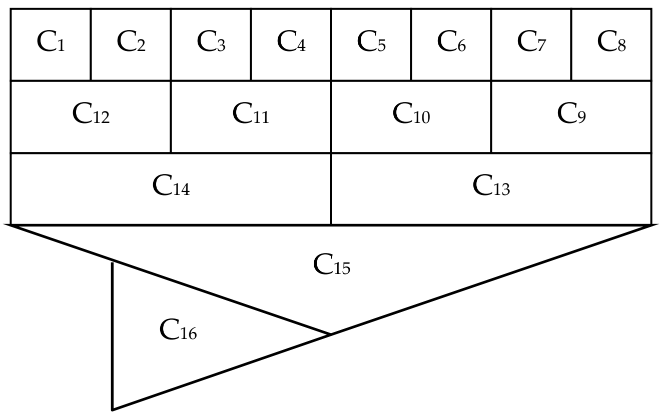

Figure 5. Formation of columns

Using the addition table in Figure 1 and applying the algorithm above, we obtain the final tableau with the 16 columns used to perform the divination. Figure 6 present an example. This tableau contains all the 16 columns. The ombiasy does not use the indexes but we use them to clarify our later work. This tableau is the base for the divination process and is organized in the way presented in Figure 6, with the mother-sikidy at the top and the newly generated columns below.

The mother sikidy and the final sikidy tableau have interesting properties no matter how the mother-sikidy comes out. This gives the ombiasy an opportunity to check the validity of the tableau.

- Property 1: The column C_{15} is called the creator. The total number of seeds in this column is always even. In our example, the total is 6 that is even.
- Property 2: Two of the sixteen columns must be the same. In our example, we have the following results:

$$C_1 = C_{13}, C_3 = C_{15} = C_{16}, C_3 = C_{14}, C_{12} = C_{14}.$$

- Property 3: The columns C_{13} and C_{16}, C_{14} and C_1, and C_{11} and C_2 are three inseparables, that is,

$$C_{13} + C_{16} = C_{14} + C_1 = C_{11} + C_2.$$

  In our example, each of the sums is C_{15}.

For the proofs of these properties we refer the reader to Ascher [4].

C_4	C_3	C_2	C_1	
o	o	o	oo	C_5
o	o	oo	oo	C_6
oo	oo	oo	o	C_7
o	o	o	o	C_8

oo	oo	oo	o	oo	o	o	o
o	oo	o	oo	oo	oo	oo	oo
o	o	oo	oo	oo	o	o	oo
o	o	oo	o	oo	oo	oo	o
C_9	C_{13}	C_{10}	C_{15}	C_{11}	C_{14}	C_{12}	C_{16}

Figure 6. The final sikidy tableau

3. Simulation of the Sikidy Divination System in Microsoft Excel

In this section we explain how to simulate the sikidy divination system in Microsoft Excel and show how to verify the properties discussed in the previous section. We created a spreadsheet to represent the 4 rows and 16 columns from the tableau. Columns C1, C2, C3, and C4 (which in Excel were represented as A, B, C, and D) were designed to choose a random integer between 0 and 1 to represent the remainder of seeds left after the ombiasy removed them from the random piles.

Build in Excel function “RANDBETWEEN(0,1)” was entered into each cell to obtain the mother sikidy. The commands for each of the cells can be seen in Figure 7.

	A	B	C	D
1	C1	C2	C3	C4
2	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)
3	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)
4	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)
5	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)	=RANDBETWEEN(0,1)
6	=MOD(SUM(A2:A5),2)	=MOD(SUM(B2:B5),2)	=MOD(SUM(C2:C5),2)	=MOD(SUM(D2:D5),2)

Figure 7: Excel commands for mother sikidy

The next columns, C5, C6, C7, and C8 (E, F, G, and H), were set up to be rows 1, 2, 3, and 4 respectively. For example, C5’s (column E) cells from top to bottom would read A2, B2, C2, D2 which would coordinate with the first row of the mother sikidy, and each of the other columns were set up similarly but with numbers 3, 4 , and 5. The input commands for columns 5, 6, 7, and 8 are shown in Figure 8.

C5	C6	C7	C8
=A2	=A3	=A4	=A5
=B2	=B3	=B4	=B5
=C2	=C3	=C4	=C5
=D2	=D3	=D4	=D5
=MOD(SUM(E2:E5),2)	=MOD(SUM(F2:F5),2)	=MOD(SUM(G2:G5),2)	=MOD(SUM(H2:H5),2)

Figure 8: Excel commands for columns 5-8

The next 8 columns were set up as combinations of two other columns following the scheme shown in Figure 5. To replicate this, the sum of each pair of columns is computed in base 2 or modulo 2. For example, C9 (I) is a combination of C7 (G) and C8 (H) and the first cell of column I would read “MOD(G2+H2,2)” . The cells below are filled down with a similar formula. The rest of C10 through C16 were computed the same way using the letters associated with the specific column. The input commands for these columns can be seen in Figure 9.

C9	C10	C11	C12	C13	C14	C15	C16
=MOD(H2+G2,2)	=MOD(E2+F2,2)	=MOD(C2+D2,2)	=MOD(A2+B2,2)	=MOD(I2+J2,2)	=MOD(K2+L2,2)	=MOD(M2+N2,2)	=MOD(A2+O2,2)
=MOD(H3+G3,2)	=MOD(E3+F3,2)	=MOD(C3+D3,2)	=MOD(A3+B3,2)	=MOD(I3+J3,2)	=MOD(K3+L3,2)	=MOD(M3+N3,2)	=MOD(A3+O3,2)
=MOD(H4+G4,2)	=MOD(E4+F4,2)	=MOD(C4+D4,2)	=MOD(A4+B4,2)	=MOD(I4+J4,2)	=MOD(K4+L4,2)	=MOD(M4+N4,2)	=MOD(A4+O4,2)
=MOD(H5+G5,2)	=MOD(E5+F5,2)	=MOD(C5+D5,2)	=MOD(A5+B5,2)	=MOD(I5+J5,2)	=MOD(K5+L5,2)	=MOD(M5+N5,2)	=MOD(A5+O5,2)
=MOD(SUM(I2:I5),2)	=MOD(SUM(J2:J5),2)	=MOD(SUM(K2:K5),2)	=MOD(SUM(L2:L5),2)	=MOD(SUM(M2:M5),2)	=MOD(SUM(N2:N5),2)	=MOD(SUM(O2:O5),2)	=MOD(SUM(P2:P5),2)

Figure 9: Excel commands for columns 9-16

Finally, in order to better visually identify characteristics, the cells were color coded using the conditional formatting option in Excel, 0’s were colored blue and 1’s were colored yellow cells. The colors change every time that a new mother-sikidy is generated. Figure 10 shows an example of a possible color-coded output for columns 1 through 16.

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
1	1	1	1	1	1	0	1	1	0	0	0	1	0	1	0
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
1	0	1	0	1	1	1	0	1	0	1	1	1	0	1	0
1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1

Figure 10: Excel output

4. Properties of the sikidy divination table in Excel

As mentioned before, there are certain relationships that the tableau must contain in order for it to be valid. These properties are always present, regardless of the original randomly generated 4x4 mother-sikidy. The ombiasy checks each of the properties before continuing with the reading. The first property is that at least two of the sixteen C_i must be the same. Secondly, when combined, C_{13} and C_{16}, C_{14} and C_1, and C_{11} and C_2 have the same results. These three pairs are called "the three inseparables". The third property is that the creator (C_{15}) must contain an even number of seeds. Ascher [2], [4], presents the mathematical proofs of all three properties. Excel is used here to show an alternative verification of the properties. Once C_1 - C_{16} are determined, the three properties can be identified using Excel.

In order to verify the first property, that at least two of the sixteen C_i must be the same, every column has to be compared to every other column. The command =AND(EXACT($A2,B2), EXACT($A3,B3), EXACT($A4,B4), EXACT($A5,B5)) is used to complete the comparison. This command compares every cell of column A (C_1) to every cell of column B (C_2). If every cell in C_1 matches the corresponding cell in the C_2, then the output of the command is TRUE. If there is even a single cell in C_1 that does not match the corresponding cell in the C_2, then the output of the command is FALSE. The command is repeated 120 times to compare every column to every other column. As seen in Figure 11, the outputs are formatted, using conditional formatting, in a way that TRUE statements will be highlighted in pink, making it easy to identify when two columns match. According to property 1, there will be at least one TRUE statement every time. For any random arrangement of C_1 through C_4 we always get a pink cell or a TRUE statement. Again, we used colors to make easier the identification of the properties. In Figure 11, the first value of True means that column 2 and column 6 are the same.

FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE		
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE			
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE				
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE					
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE						
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE							
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE								
FALSE	FALSE	FALSE	FALSE	FALSE	FALSE									
FALSE	FALSE	FALSE	FALSE	FALSE										
FALSE	FALSE	FALSE	FALSE											
FALSE	FALSE	FALSE												
FALSE	FALSE													
FALSE														

Figure 11: Property 1 in Excel

In order to check the second property, the combinations of C_{13} and C_{16}, C_{14} and C_1, and C_{11} and C_2 must be checked. To do this, we added the columns together modulo 2. For example, since C_{13} is column M and C_{16} is column P, the command MOD(M2+P2,2) is used for the first row, and the numbers are increased to 3, then 4, then 5 for each row after that. This process is repeated for C_{14} and C_1, and C_{11} and C_2. This gives a set of three columns which again are color coded to make the results easier to identify. The input commands are shown in Figure 12 and an example of resulting outputs can be seen in Figure 13. For any random arrangement of C_1 through C_4 we always get these three columns identical.

C13*C16	C14*C1	C11*C2
=MOD(M2+P2,2)	=MOD(N2+A2,2)	=MOD(K2+B2,2)
=MOD(M3+P3,2)	=MOD(N3+A3,2)	=MOD(K3+B3,2)
=MOD(M4+P4,2)	=MOD(N4+A4,2)	=MOD(K4+B4,2)
=MOD(M5+P5,2)	=MOD(N5+A5,2)	=MOD(K5+B5,2)

Figure 12: Excel commands for Property 2

C13*C16	C14*C1	C11*C2
1	1	1
0	0	0
1	1	1
0	0	0

Figure 13: Property 2 in Excel

To check the last property, the sum of the entries in C15 will be always 0 (mod2), the sum of the values of each column are found by entering "MOD(SUM(A1:A5),2)" for all of the 16 columns using the correct letter. By looking at the last row of C15, we see that no matter what the mother-sikidy is, the sum of C15 will always be zero. To make this more visible, if the sum of C15 is 0, the cell will appear orange, using again conditional formatting. This can be seen in Figure 14. For any random arrangement of C1 through C4 we always get a 0 in the fifth row of C15.

C15
1
0
0
1
0

Figure 14: Property 3 in Excel

This combination of the use of colors and the functions from the spreadsheet provide a visual demonstration of the properties, independent of the initial C1 to C4 columns. The next step is to generalize the creation of the sikidy and use the same method to explore the properties of the new sikidy.

5. A Generalization of the Sikidy Divination Table in Excel

In order to explore a possible generalization of these properties with an expanded Sikidy, a mother-sikidy of 8 by 8 was created instead of a 4 by 4. Even though the enlarged Sikidy would not serve the same purpose in the divination process, the goal was to examine the mathematical properties.

In order to create an 8 by 8 Sikidy, the basic idea of the diagram of the 4 by 4 Sikidy can be mimicked. In the diagram of the 4 by 4 Sikidy there are 8 sections in the top row (see figure 5), followed by 4 sections in the next row, then 2 sections in the third row, then 1 section, and finally a last part that theoretically connects to the first box. In order to change this diagram to represent an 8 by 8 sikidy, 16 sections in the top row (labeled 1 through 16 going left to right) are used, then 8 sections in the second row (labeled 17 through 24 going right to left, then 4 sections in the third row (labeled 25 through 28 going right to left), then 2 sections in the fourth row (29 and 30 going right to left), and finally section 31 in the last row, and section 32 off to the side to show that it is combined with the first section. This can be seen in the Figure 15.

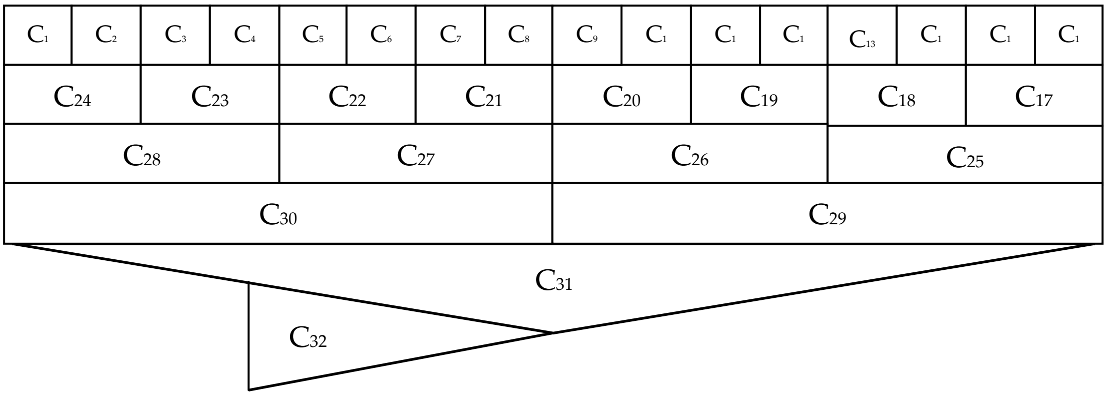

Figure 15: Formation of columns with an 8x8 mother sikidy

The method used for the 4 by 4 Sikidy was used here to enter the new 8 by 8 arrangement in Excel. However, it has 8 columns of random integers either 0 or 1 (columns A through H). Then 8 columns (I through P) are set up to be the rows of columns A through H. Column I was row 1 of the first 8 columns, column J was the second row of the first 8 columns, and so on until column P, which is row 8 of the first 8 columns. The rest of the columns (Q through AF) were set up as combinations of two other columns as shown in Figure 15 and computed in mod (2).

To look at the properties of the new Sikidy, the sum of the values of each column are found, each of the cells are color coded, and a comparison of every column to every other column is set up using the same Excel commands as before.

One thing that was interesting about the 8 by 8 Sikidy is that only two of the three properties held. We color-coded all the cells in a similar way we did for the 4 by 4 and use the colors to help us understand the properties. Then we proved which properties were true for the new Sikidy.

The first property that there must be two C_i that are exactly the same did not hold. When every column is compared to every other column in the 8 by 8 Sikidy, it can be seen that in some of the random generations there were no two columns that were the same. This was due to the fact that there were 8 rows in the 8 by 8 Sikidy; each row has two options (0 or 1), so there are 256 (2^8) possibilities for each column, while there are only 32 columns in the 8 by 8 sikidy. This means that it is very likely that all of the 32 columns could be different. It is possible for an output not to show a single 'TRUE' statement, which means no two columns match.

The next property, that there are "three inseparables", did hold. In the 4 by 4 Sikidy, the "three inseparables" were C_{13} and C_{16}, C_{14} and C_1, and C_{11} and C_2. To begin proving it for the 8 by 8, the placement of C_{13} and C_{16} in the 4 by 4 is examined and the columns with the same placement in the 8 by 8 diagram are used. It begins with the combination of C_{29} and C_{32} and continues with the columns were combined to create them. The proof can be seen below.

$$C_{29} + C_{32} = C_{29} + (C_{31} + C_1) = C_{29} + (C_{30} + C_{29}) + C_1$$
$$= C_{30} + C_1$$

$$C_{30} + C_1 = (C_{28} + C_{27}) + C_1 = (C_{24} + C_{23}) + C_{27} + C_1$$
$$= (C_1 + C_2) + C_{23} + C_{27} + C_1 = C_2 + C_{23} + C_{27}$$

From this process the inseparables-C_{29} and C_{32}, C_{30} and C_1, and C_2, C_{23} and C_{27}-are found. It is important to note that the combination of a column with itself results in a zero column, and therefore can be taken out of the equation. This is because addition modulo 2 is being used and values are only identified as either even or odd. Two times any number is even, so two times any column is even, and therefore zero.

Finally, the third property, that C_{15} should always be even, is examined. In the 4 by 4 diagram, C_{15} is in the same place as C_{31} is in the 8 by 8 diagram. We explore the sum of column C_{31} to see if the property was still true. It can be noted that C_{31} is always an even number of seeds. In order to prove this, we traced what columns are combined to create C_{31}. C_1, C_2, C_3, and C_4 are columns of the randomly generated 8 by 8 mother-sikidy grid. C_5, C_6, C_7, and C_8 are the rows of the randomly generated 8 by 8 mother-sikidy grid. Therefore, C_1-C_4 and C_5-C_8 are made up of all the same elements, just arranged in a different order. Since C_{31} can be traced back to a combination of C_1 through C_8, it essentially contains every element of the mother-sikidy twice. As previously stated, every number multiplied by two results in an even value, which is denoted by a 0. Therefore, C31 will always have a sum of 0 and be the creator.

6. Conclusion

There are three identifying properties of a Sikidy with a 4 by 4 mother-sikidy, and only two of the three properties hold when the mother-sikidy is expanded to 8 by 8. The properties could be further investigated using a 16 by 16 mother-sikidy. Microsoft Excel could be used to determine whether or not 16 by 16 sikidies possess the same two properties of an 8 by 8, only one property, or none at all.

Ethnomathematics relates mathematics and cultural activities. Many times, the mathematical ideas embedded in these activities are very sophisticated. While the ombiasy uses seeds to perform divination and create a Sikidy to guide others, technology can be used to examine the properties of the process and results. Just like the mathematical qualities of the Malagasy Sikidy are generalized using Microsoft Excel, the same can be done in other areas of ethnomathematics. In our undergraduate program the research component is integral to the development of students' mathematical experience. We hope that this example of the use of technology to study the mathematics behind cultural activities will encourage other to take on similar projects.

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