

## Fresh aspects of geometry, algebra and calculus in PNG stamps and traditional house wall patterns

Thadreina Abady

### Abstract

This paper presents some fresh aspects of studies that integrate geometry, algebra, trigonometry and calculus in some PNG cultural features such as traditional house wall patterns and PNG stamps through the use of Microsoft Excel. In order to represent these features visually in Excel, we generate the  $(x,y)$  coordinates of mathematical functions in Excel such as cosine and sine and use the XY scatter graph feature to generate curves to display the geometrical features that are discussed in this paper. The traditional houses or huts which still exist today in all native villages of the country are built mostly by using bush materials. The woven house walls display basic geometrical shapes such as diamonds, squares and triangles. The stamps are depict aspects of PNG culture such as flowers, clay pots, village houses, birds, butterflies and others. The paper concludes with a discussion of the method used and suggestions for future improvements and extensions in the use of the creative mathematics employed in the examples that we illustrate in Excel.

**Key words:** algebra, geometry, calculus, sine, cosine, polar coordinate, Cartesian coordinate

### Introduction

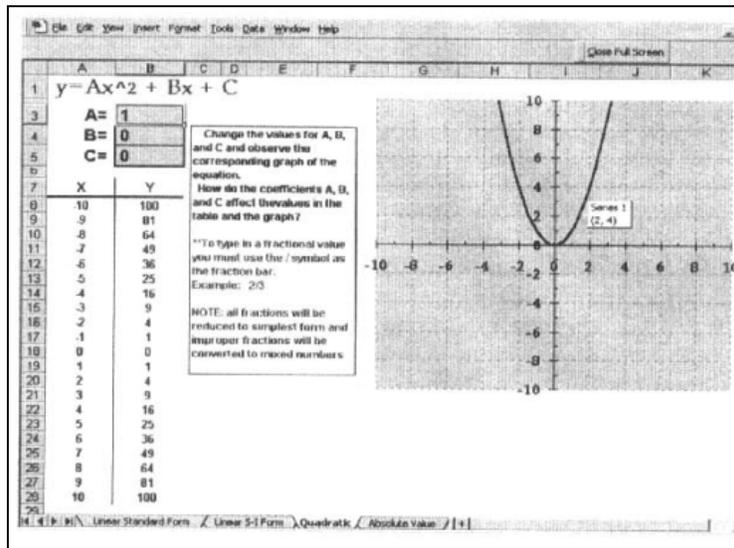
Inspired by the extensive uses of Microsoft Excel in education, engineering, science and technology, various applications of the real world can be easily modelled and then analyzed to improve processes and professional practices within an organization (Blum, 2007). One of the potential uses of spreadsheet lies in mathematics education where this paper explores further applications using Papua New Guinea (PNG) cultural features such as PNG stamps and traditional house-wall patterns. These items, as the study shows, hold rich potential for the integration of algebra, geometry, trigonometry and calculus concepts. The features mentioned above are illustrated using the sine and cosine functions of Microsoft Excel. These inbuilt functions allow us to generate a series of  $(x,y)$  coordinates and then visually represent the coordinates on an XY scatter chart.

### Background

Microsoft Excel was one of the first electronic spreadsheet that started in late 1970's by Dan Bricklin and Bob Franklyn (Bricklin, 1999). This tool was invented primarily to replace some of the tedious tasks that accountants and businesses alike faced whilst trying to do complex calculations. The

applications of the Excel spreadsheet in business processes have been around for some time now, so that the concept of using spreadsheets in the business world may not be a new one. However, what seems to become an emerging trend is the use of the Excel spreadsheet in the areas of science and mathematics education. This is because Microsoft Excel has the ability to allow visual interaction whereby students can explore alternative solutions, thus providing an opportunity for students to gain a deeper understanding of concepts embedded within a problem.

Drier (2001), in her research of teaching and learning with interactive spreadsheets, found that spreadsheets can create a dynamic environment for discovering mathematical relationships. The spreadsheet Excel supports features like cells, inbuilt functions, and graphs which when referenced together in a formula all become linked together (Drier, 2001, p. 171). This powerful capability of Excel provides an interactive environment where students can further experiment and explore mathematical concepts. Drier supports her findings with examples. In Figure 1, she shows an example about how a spreadsheet can be used to generate a series of (x,y) coordinates in a given table by adjusting coefficients A, B or C in a general quadratic equation  $Ax^2+Bx+C$ .



**Figure 1: Interactive spreadsheet for exploring transformations using a quadratic function and viewing multiple representation**

What happens in the process is that when students change the values in either A, B or C, the spreadsheet recalculates the formula in cells such as B8 ( $=B3*A8^2+B4*A8+B5$ ) which are dependent on those values (A, B and C). When a change is made, it is instantaneously reflected on both the XY table as well as on an XY scatter chart (Drier 2001, p. 172). This symmetric shape of the quadratic function given above can be seen in both the table and the graph.

In Figure 2, Drier further highlights an important aspect of how interactive charts can be utilized to stimulate additional discussions in the symmetric shape of the graph of the function. She demonstrates this by changing the value of C several times. For example, when users set the value of C to 3 it can be observed that all the squared numbers from the function  $y = x^2$  increase by 3, and that is portrayed graphically with  $y=x^2+3$ . She then summarizes that when students change the value of C several times, they can make observations and quickly conclude that the C value determines the vertical shift in the graph when  $B=0$ , and that it will also be the y-intercept no matter what values A and B take.

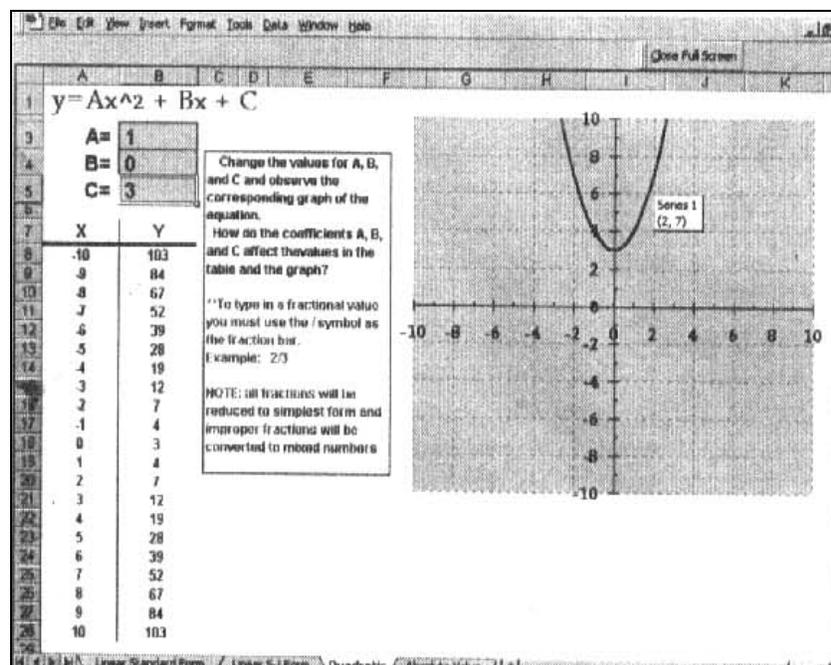
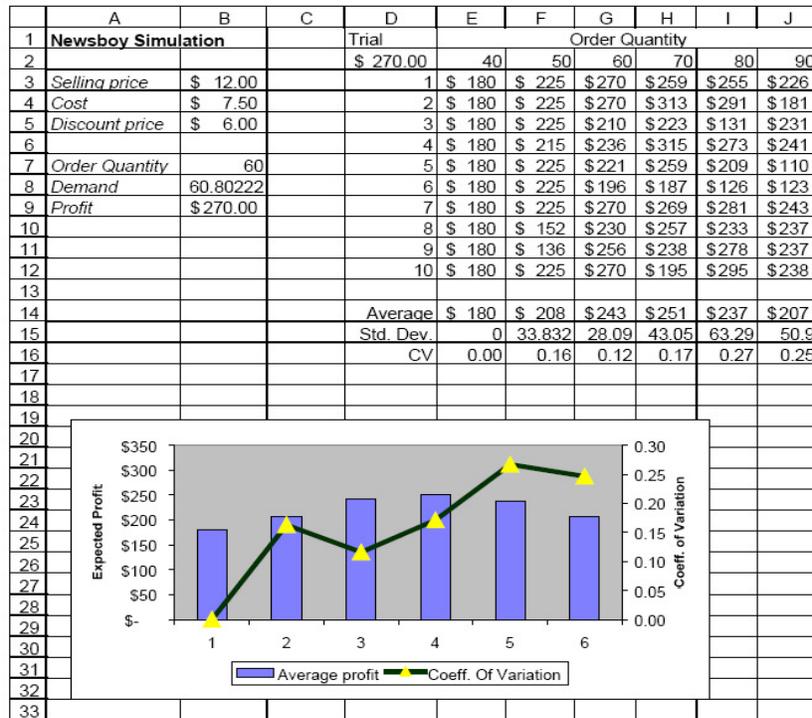


Figure 2: Multiple representations of  $y=1x^2+3$

In another study titled 'Spreadsheet as a tool for teaching simulation' by James Evans, he describes the spreadsheet as a simulation tool with pedagogical advantages. One of those advantages that he lists is the *dynamic update* of spreadsheet. He, too, supports Excel spreadsheet as an ideal tool for teaching and learning of dynamic systems (Evans, 2000, p. 27). Evans demonstrates the above with examples. In Figure 3, he illustrates an example of a financial model where students adjust the discount rate, price and cost and observe the expected generated profit.



**Figure 3: Spreadsheet model and data table simulation of a newsboy problem**

Whilst the discussed literature promotes Excel as a dynamic interactive tool for student learning, other researchers discuss the risks associated with trying to facilitate learning of mathematics using computer-aided tools. Clarke (2005) investigated possible risks associated as result of learning Excel features and mathematical concepts concurrently. The findings show that prior spreadsheet skills were necessary and must be learned first before mathematical concepts are taught using tools such as Excel (Clarke, 2005, p. 22). What Clarke also found was that when relevant spreadsheet skills are learnt prior to studying mathematics, students are able to integrate mathematical concepts into spreadsheet more effectively as they have sufficient computer skills and knowledge. Those findings suggest that learning both technology and mathematical concepts concurrently may only be effective if learners already have considerable technological knowledge (Clarke, 2005, p. 23).

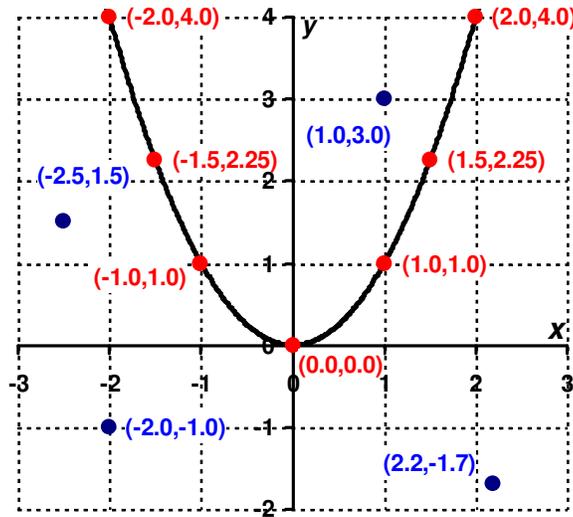
Using computer-aided software to facilitate the creative teaching and learning of mathematics was not popular in PNG until the late 1990s (Arganbright, 1998). At the University of Papua New Guinea, incorporating application programs such as spreadsheet, particularly in mathematics education, was not a common practice even though it was seen as necessary for skills development. The reason is because most academics at that time did not have adequate computer training to facilitate computer-based learning (Arganbright, 1998, p.

104). From his classroom experience, students were able to experiment and investigate mathematical models in physics, epidemics and statistics using Excel spreadsheet. At the PNG University of Technology in Lae, Morobe Province, students felt confident in exploring mathematical concepts without much supervision (Majewski, 1995). Majewski found that computer learning technologies, such as spreadsheets, encouraged students to think analytically and critically individually when solving a mathematical problem.

In this paper most of the examples are illustrated in Microsoft Excel version 2003. The examples used can also be developed in later versions of Excel. The examples illustrate fundamental mathematical concepts such as those found in algebra, geometry, trigonometry and calculus and depict PNG stamps and traditional house wall or hut patterns in Papua New Guinea. The wall patterns still exist today in all native villages which are built mostly by using bush materials. These house walls display common basic geometrical shapes such as diamonds, squares and triangles.

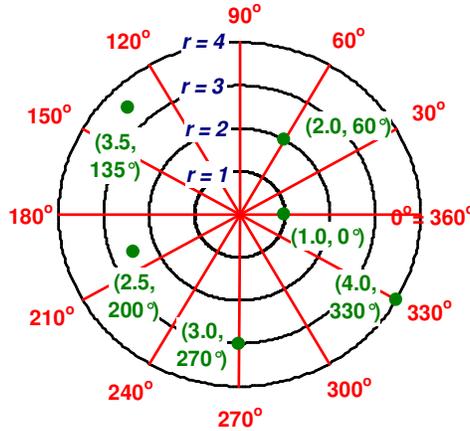
**Cartesian and polar coordinates**

There are two coordinate systems that are used to create geometric curves. In algebra we usually use the Cartesian or rectangular coordinate system (Newwirth, 2004). In this system we employ two perpendicular axes, the *x*-axis and the *y*-axis. Cartesian coordinates are represented by the horizontal run, *x*, and the vertical rise, *y*. Points on a curve are determined by the formula for a function of the form  $y = f(x)$  (Newwirth, 2004, p. 211). Figure 4 below shows a curve formed by plotting  $(x,y)$  coordinates of the function  $y = f(x) = x^2$ , with selected points on the curve shown in red. We also plot a few additional points not on the curve in blue.



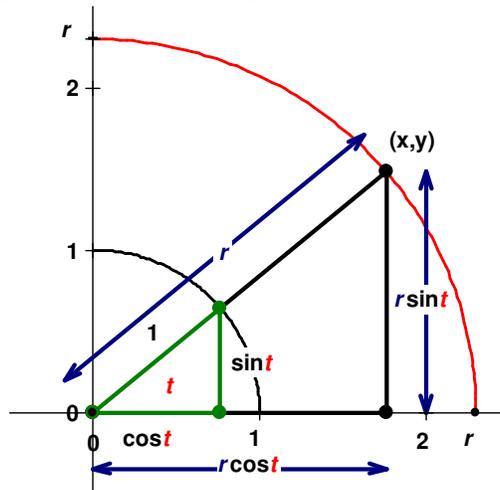
**Figure 4: Polar and Cartesian coordinates**

In the polar coordinate system we plot points by polar coordinates  $(r,t)$ , where  $r$  is the distance of the point from the origin,  $(0,0)$  and  $t$  is the angle between the positive  $x$ -axis and a line from the origin to the point. Angles are measured in an anticlockwise fashion (Newwirth 2004, pp. 212-213). Figure 5 illustrates both the grid of concentric circles ( $r$  values) and radii from the origin ( $t$  values). In Figure 5 we have shown the angle measurements in degrees. However, mathematical functions require angles to be measured in radians ( $360$  degrees =  $2\pi$  radians). Excel provides a function to do the conversion for us, with radians expressed as decimals (i.e.  $\pi$  is shown as 3.14159).



**Figure 5: Polar angles measurement in degrees**

Although Excel does not provide a polar chart type, we can convert from polar to Cartesian coordinates by using some ideas from trigonometry:  $x = r\cos t$ ,  $y = r\sin t$ . This is illustrated in Figure 6. We use polar coordinates for most curves in this paper beginning with PNG stamps.



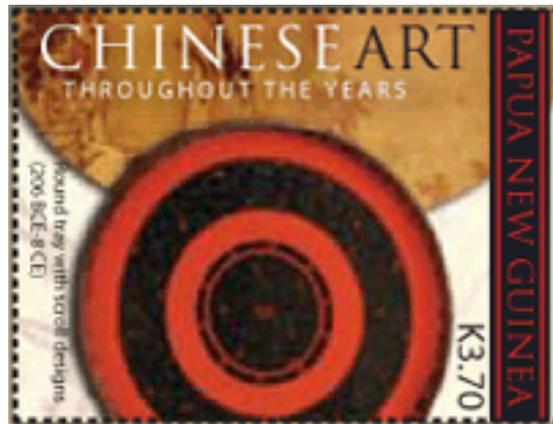
**Figure 6: Converting polar to Cartesian coordinates**

## PNG Stamps

The PNG stamps are part of modern art, and the characters that the stamps depict are rare species of PNG nature such as orchids, butterflies, frangipanis and others. Like most published stamps in countries abroad, PNG stamps also try to capture significant social and economical developments, achievements, worthy campaigns, extinct animals, artefacts and plants as well as traditional cultures preserved over the years. You can visit the website [www.postpng.com.pg/philatelic.htm](http://www.postpng.com.pg/philatelic.htm) to know more about stamp history. Out of those that I have mentioned, I have chosen only a few which could be easily used to show the geometric curves found on them (stamps).

In order to represent the geometric curves found on the stamps and house wall patterns visually in Microsoft Excel, we generate a series of  $(x,y)$  values. To do this we use mathematical functions in Excel such as cosine and sine. These coordinates are then graphed on an XY scatter charts to show the geometric curves. In the following examples we provide brief descriptions of the Excel creation process. Detail descriptions of the steps involved are presented in a more general setting on the Web site [www.pngalphabets.dwu.ac.pg](http://www.pngalphabets.dwu.ac.pg).

Our first example of a PNG stamp depicts a Chinese round tray shown in Figure 7 made out of red clay.



**Figure 7: A PNG stamp of the Chinese round tray**

To illustrate the geometric curve of the above round tray, in the first column we find the angles measured in degrees. We do this by starting with zero in the first cell and then adding 1 to the cell above as shown in Figure 8. Then we do an auto-fill of the generated values up to 360 degrees.

4								
5		n (deg)	t (rad)	x1	y1	x2	y2	
6		0						
7		=1+C6						
8								

**Figure 8: Degree counter column = 0+1**

In the second column  $t$  we then convert the degree values in the first column to radians as shown in Figure 9. This is so that we can easily represent the geometric curve using polar equations.

3								
4		n (deg)	t (rad)	x1	y1	x2	y2	
5		0	0					
6								
7		1	=RADIANS(C7)					
8								

**Figure 9: Converting degree to radians using radians function**

In the third column  $x1$ , we then use the trigonometry function  $x = r\cos t$ ,  $y = r\sin t$  to find the corresponding  $x$  and  $y$  coordinates from a known radians of 1 to 4. Our radians are highlighted in blue font as shown in Figure 10.

1	<b>equation: <math>x=1*\cos(t)</math>, <math>y=1*\sin(t)</math></b>							
2								
3		n (deg)	t (rad)	x1	y1	x2	y2	x3
4								
5		0	0	1				
6								
7		1	0.01745	= $\$E\$4*\text{COS}(D7)$				
8								

**Figure 10: Employing the polar equation  $x=r\cos(t)$ ,  $y =r\sin(t)$**

Figure 11 shows a set of  $x$  and  $y$  coordinates generated after doing the steps described above.

2	<b>equation: <math>x=1*\cos(t)</math>, <math>y=1*\sin(t)</math></b>									
3										
4										
5	n (deg)	t (rad)	x1	y1	x2	y2	x3	y3	x4	y4
6	0	0	1	0	2	0	3	0	4	0
7	1	0.017453	0.999848	0.017452	1.999695	0.034905	2.999543	0.052357	3.999391	0.06981
8	2	0.034907	0.999391	0.034899	1.998782	0.069799	2.998172	0.104698	3.997563	0.139598
9	3	0.05236	0.99863	0.052336	1.997259	0.104672	2.995889	0.157008	3.994518	0.209344
10	4	0.069813	0.997564	0.069756	1.995128	0.139513	2.992692	0.209269	3.990256	0.279026
11	5	0.087266	0.996195	0.087156	1.992389	0.174311	2.988584	0.261467	3.984779	0.348623
12	6	0.10472	0.994522	0.104528	1.989044	0.209057	2.983566	0.313585	3.978088	0.418114
13	7	0.122173	0.992546	0.121869	1.985092	0.243739	2.977638	0.365608	3.970185	0.487477
14	8	0.139626	0.990268	0.139173	1.980536	0.278346	2.970804	0.417519	3.961072	0.556692
15	9	0.15708	0.987688	0.156434	1.975277	0.312869	2.962065	0.460202	3.950752	0.625738

**Figure 11: Spreadsheet showing a series of  $x$  and  $y$  points for radians 1 to 4**

In Figure 12 we then try to represent the corresponding  $x$  and  $y$  points for the radians 1 to 4 respectively, on a XY scatter chart. To do this, first of all we select the  $x$  and  $y$  points of radians 1 given in columns  $x_1$  and  $y_1$  and then we plot these selected points on the XY scatter chart.

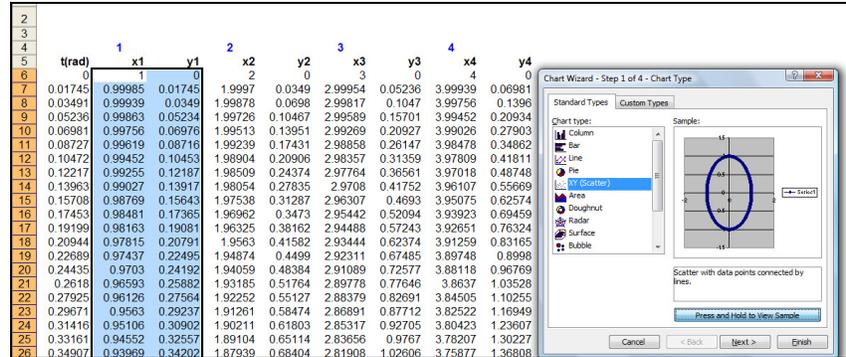


Figure 12: Representing  $x$  and  $y$  on an XY scatter chart

We repeat the steps described above for the remaining radians. However, to represent all the radians on the same scatter chart we perform a simple graphing technique. We do this by selecting points denoted by  $x_2$  and  $y_2$  and then dragging the selected points onto the scatter chart. When that is done a paste special dialog box will appear (as shown in Figure 13), asking you to set your new series points with a new category name. These options allows for the new radian to appear on the graph.

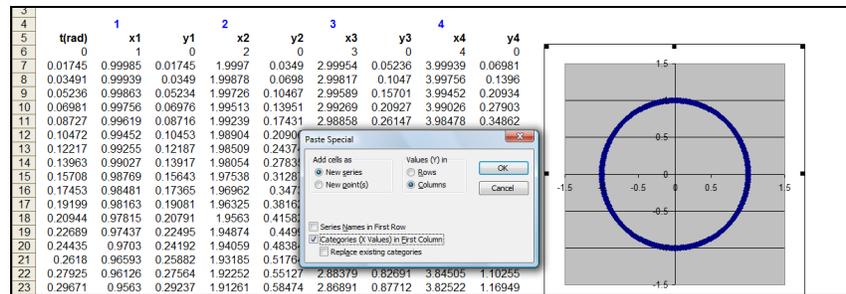
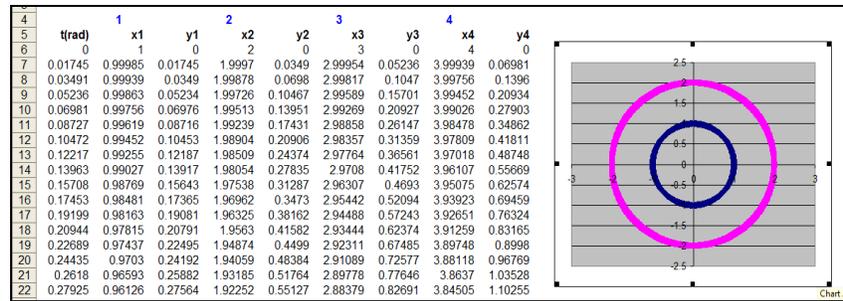


Figure 13: Graphing additional  $x, y$  coordinates onto the XY scatter chart

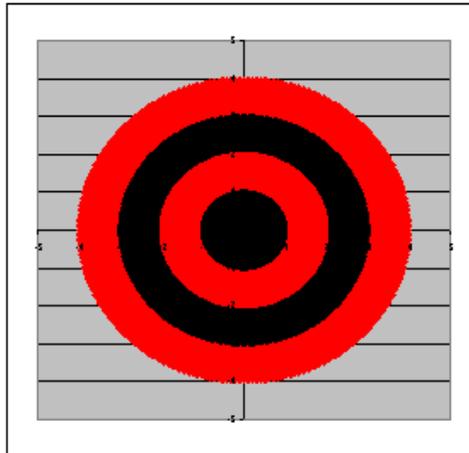
Figure 14 given below, shows what happens after we click on the OK button. Immediately a new circle appears. We repeat the same processes described above until we get all 4 circles.



**Figure 14:** Shows the second radians after graphing given known  $x$ ,  $y$  coordinates

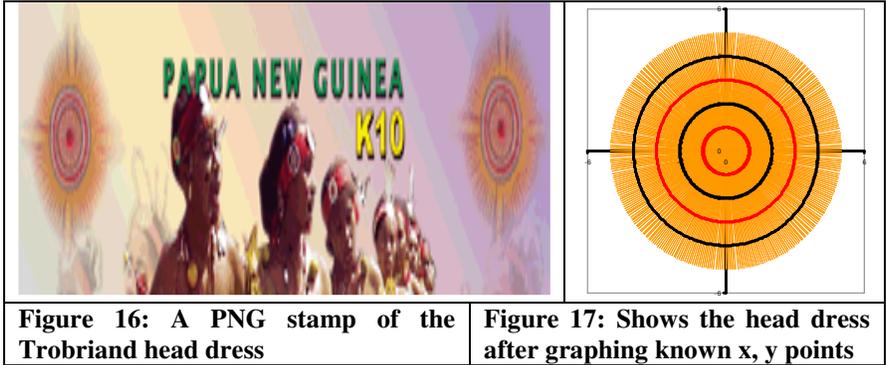
When the above steps have been fully completed, we then generate a series of  $x$  and  $y$  points on the same worksheet that will become our fill-in points for each of the radians. The steps to creating a separate series of  $x$  and  $y$  fill points to the filling in of each of the radians follows similar techniques to get the  $x$  and  $y$  coordinates showing on the right of the graph above, as well the graphing technique of selected points. To know more about the detailed steps please visit the website [www.pngalphabets.dwu.ac.pg](http://www.pngalphabets.dwu.ac.pg).

After we fill in the points for radians 1 to 4, we end up with a similar design on the XY scatter chart. Given below, figure 15 shows you the geometric pattern of the Chinese round tray, generated using Excel's mathematical function.



**Figure 15:** Shows the complete graph after graphing a series of  $x$ ,  $y$  coordinates

Our second example shows the Trobriand Island headdress in Figure 16. This address is made from a special material and worn around the head during a traditional occasion. The pattern of this unique headdress can also be represented using the trigonometry equation  $x=rcost$ ,  $y=rsint$ . Figure 17 shows the headdress in Excel after we graph the coordinates using the trigonometry function  $x = rcost$ ,  $y = rsint$  to find the corresponding  $x$  and  $y$  coordinates. The graphing technique used in this example of the head dress is similar to that of the Chinese round tray described earlier on.

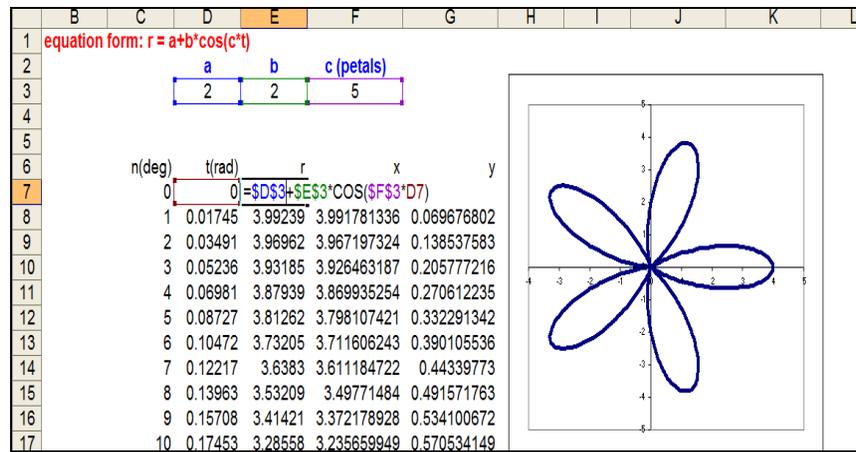


In our third example (see Figure 18) inspired by the PNG stamps, we take a look at the Frangipani. This flowering plant grows all year round in almost all the parts of Papua New Guinea and is often used for ceremonial decorations in many social and traditional gatherings.



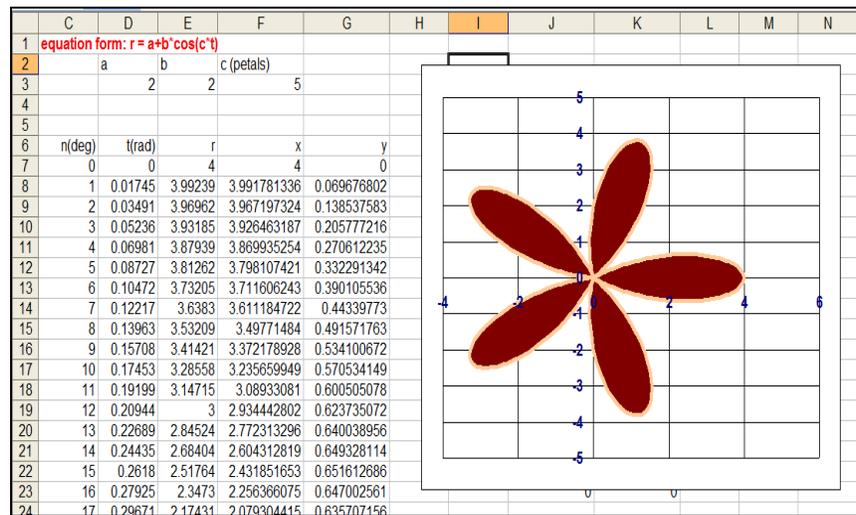
**Figure 18: A PNG stamp collection of frangipani flowers**

Unlike the previous examples, the patterns on the frangipani flower is created and plotted on an XY scatter chart using the polar equation  $r = a + b\cos(ct)$  as shown in Figure 19 below.



**Figure 19: Graphing a frangipani flower using polar equation  $r = a + b \cos(ct)$**

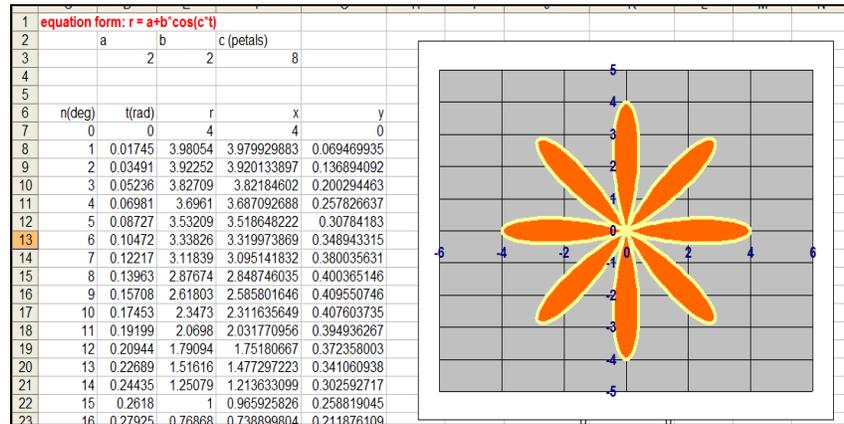
We then convert the polar expressions in  $r$  column to Cartesian coordinates in  $x$  and  $y$  columns respectively, using the equations  $x = r \cos(t)$  and  $y = r \sin(t)$ . After the above steps have been fully completed we then plot the series of  $x$  and  $y$  points on the XY scatter chart. Figure 20 below, shows a complete frangipani flower after we fill in the points.



**Figure 20: Geometric curve of a frangipani after plotting known  $x$  and  $y$  values using the equation  $x = r \cos(t)$  and  $y = r \sin(t)$**

As discussed in the literature review (Drier, 2001) and (Evans, 2000) respectively, in this example (frangipani flower) the parameter values  $a$ ,  $b$  and  $c$  can be manipulated by students to produce the different patterns that this

image on the graph tries to capture. For example, by changing the variable  $c$  to 8 another flowering pattern (like that of a daisy) becomes visible as showing below in Figure 21.



**Figure 21: Manipulating variable  $c$  in order to see changes in the flower patterns**

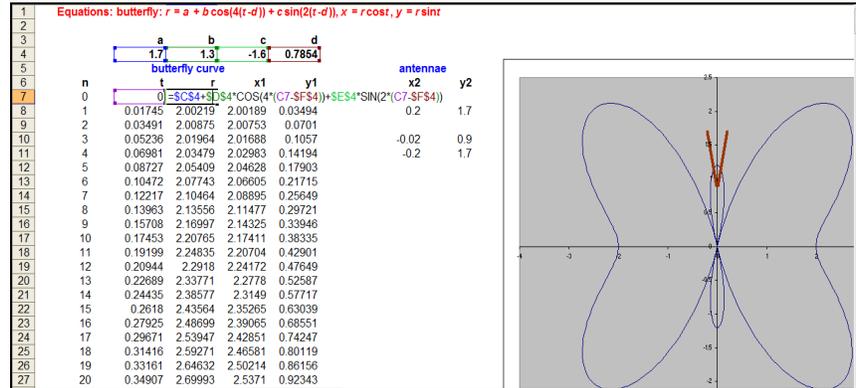
Now let us look at another example that uses Excel’s mathematical functions to create a drawing that is inspired by a PNG stamp. Figure 22 shows the *Taenaris catops* butterfly from Oro Province of Papua New Guinea.



**Figure 22: A PNG stamp of the *Taenaris Catops* butterfly**

This butterfly is normally found in the tropical climate and is famous its black spots found on the wings. The geometric curve of the butterfly is illustrated in spreadsheet using the polar equation  $r = a + b \cos(4(t-d)) + c \sin(2(t-d))$ ,  $x = r \cos(t)$ ,  $y = r \sin(t)$  for the indicated values of  $a$ ,  $b$ ,  $c$  and  $d$ . Similar to the first two examples described earlier on, we begin with the  $n$  counter or the degree

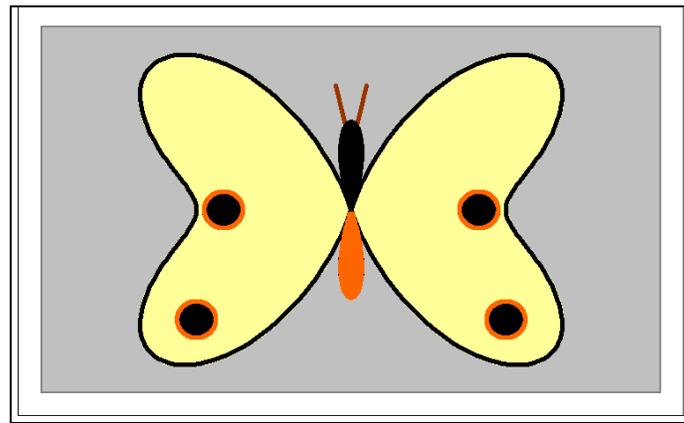
column and then convert our degree column to radians in our  $t$  column (see Figure 23 below).



**Figure 23: The butterfly curve using the equation  $r = a + b\cos(4(t-d)) + c\sin(2(t-d))$**

In column  $r$  we then use the above function  $r = a + b\cos(4(t-d)) + c\sin(2(t-d))$ . The butterfly curve (in Figure 23 above) is then plotted using the  $x$  and  $y$  points. These points are calculated in the formula  $x = r\cos(t)$ ,  $y = r\sin(t)$ .

Figure 24 below, shows four black dots on the butterfly. These four dots were created using the parametric equations:  $x = (\text{scale } x)\cos(t) + \text{trans } x$ , and  $y = (\text{scale } y)\sin(t) + \text{trans } y$ . The scale values allow us to regulate the horizontal and vertical sizes of the dots, while the trans (for translation) values allow us to vary the horizontal and vertical location of the dots. This enables the dots to fit on the four quadrants of the butterfly with respective fill coordinates generated from the  $x$ - and  $y$ -values of points on the butterfly curve.



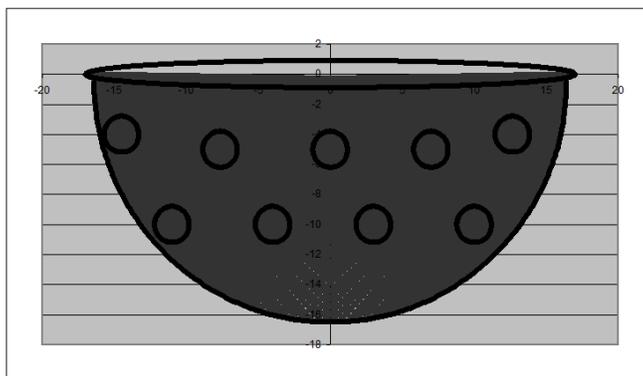
**Figure 24: Butterfly spots using the equation  $x = (\text{scale } x)\cos(t) + \text{trans } x$ , and  $y = (\text{scale } y)\sin(t) + \text{trans } y$**

This next example of another interesting feature that is also found in the collection of PNG stamps is the clay pot, in Figure 25.



**Figure 25: A PNG stamp of the clay pot**

Figure 26 below, shows the complete claypot after using the same techniques and steps we demonstrated in the butterfly curve. Here we use two equations. Both the base of the pot and the ellipse of the top opening were created using the equations of the form  $x = a_1\cos(t) + b_1$ ,  $y = a_2\sin(t) + b_2$ . We observe that if the  $x$ - and  $y$ -scaling factors  $a_1$  and  $a_2$  are equal, then we obtain a circle, while if they are different then we obtain an ellipse.



**Figure 26: An XY representation of the Claypot given the equation  $x = a_1\cos(t) + b_1$ ,  $y = a_2\sin(t) + b_2$**

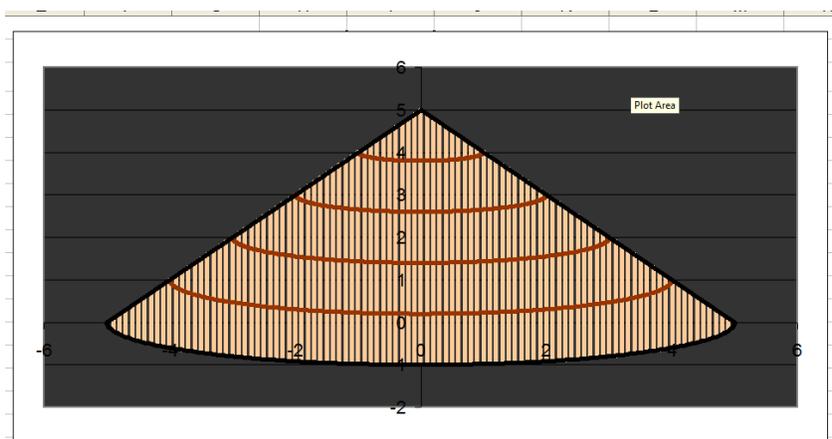
Excel as we have seen, provides a good avenue to visually represent the mathematical aspects of polar and parametric equations. Thus, provides a stimulating avenue for students to appreciate the relationship of polar and parametric equations.

The geometric curves of the discussed features above use polar and Cartesian coordinates extensively, however, other applications such as calculus and algebra can also be investigated (Zill, 2009). For example, in calculus the ellipse equation discussed above can be used to illustrate the relationship between the orbit of the moon and the position of planets in orbit (Zill, 2009, pp. 550-552). The applications of polar equations can also be used to explain the Newton's theory of gravity or the flight path of an object together with its height ( $y$  coordinates) above the surface ( $x$  coordinates) at a known angle ( $\theta$ ) (Newwirth, 2004, pp. 107-116).

Besides our illustrations of the PNG stamps, we have also tried to investigate mathematical concepts discussed above which are also applicable to other forms of art in the PNG context. We extend our explorations into the Highlands round house and the wall patterns.

### The highlands round house (roof and wall)

Figure 27 below shows a roof top of the highlands round house structure, which also uses the same parametric equations  $x=(\text{scale } x)\cos(t) + \text{trans } x$ , and  $y = (\text{scale } y)\sin(t) + \text{trans } y$  as used above for the butterfly dots and the claypot curve to create the elliptical base of a round house roof, as well as the other curves that help to display the curvature of the roof. The peak is formed by plotting a series of three  $(x,y)$  point coordinates: leftmost curve point, top point, rightmost curve point.



**Figure 27: An XY representation of the Highlands round house roof-top, given the equation  $x=(\text{scale } x)\cos(t) + \text{trans } x$ , and  $y = (\text{scale } y)\sin(t) + \text{trans } y$**

In Figure 28 given below we see the round house in actual view, while in Figure Z we view the geometric representation after plotting x and y coordinates.



Figure 28: The highlands round house in actual view

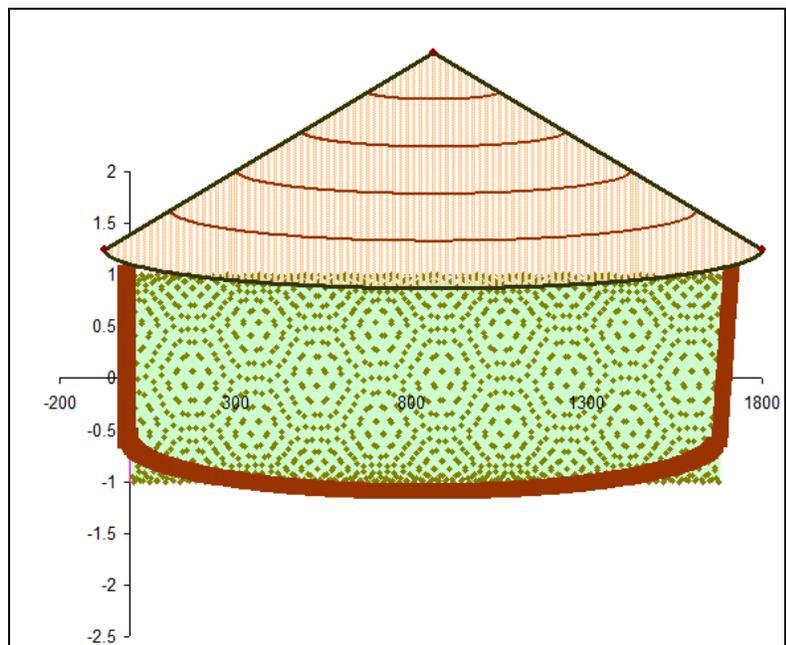


Figure 29: The n, y representation of the Highlands round house on the XY scatter chart in the equation  $x = \cos(a * n)$ ,  $y = \sin(a * n)$

Figure 29 shows a complete house wall pattern that uses only one variable to determine its corresponding  $x$ - and  $y$ -coordinates. The wall pattern uses the equation  $x = \cos(a * n)$ ,  $y = \sin(a * n)$ . Interestingly, what we represent on the XY graph is the  $n$  (degree) and the  $y$  axis values which illustrate a knitted pattern to that of a real highlander house wall. The normal representation of  $x$  and  $y$  points as illustrated in the previous examples of the PNG stamps, could not be employed in the house wall pattern as it does not clearly show the knitted patterns that we were looking for.

From the above examples we can see that the graphs generated do not portray all of the details of the object found on the stamps and house wall patterns. Providing additional features makes for good student projects. However, despite the fact that spreadsheet does have its own limitations in generating more detailed geometric shapes; what is more intriguing is the ability of spreadsheet to investigate mathematical concepts using cultural features. The above examples of traditional features found on stamps and the house wall pattern do provide an avenue for students to think creatively and openly about the capabilities of spreadsheet whilst further experimenting with various objects found in PNG's diverse culture.

Almost all the examples discussed made use of the polar equation ( $r=a+b\cos(ct)$ ,  $x = r\cos(t)$ ,  $y=r\sin(t)$ ) and at some stages some examples (butterfly, claypot and roof top) employed different parametric equations to be able to carefully illustrate the sophisticated geometric patterns that is found on them. The house wall pattern does not make use of the above polar equation and this is one of our challenges to expand our research on similar examples in this particular area in the not so distant future.

### Conclusion

It is evident that spreadsheets provide extensive capabilities for using the inbuilt formulas and functions to graph geometric curves found on the cultural features displayed on stamps as well as house wall patterns. What is also educational about this study is that with the accessibility of spreadsheet at schools or in the workplace, users can explore and experiment for themselves with different ideas and concepts of interest which are applicable to them. Similarly, this study as we have seen indicates how indigenous features which are applicable to the PNG context are used to discover the fresh aspects of geometry, algebra and calculus.

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**Additional reference sites:**

<http://www.pngalphabets.dwu.ac.pg>

<http://www.postpng.com.pg/philatelic.htm>

**Author**

Thadreina Abady comes from Madang and has a Bachelor degree in Information Systems. She is a senior tutor in the department of Information Systems at Divine Word University. She has presented research papers internationally in Beijing, China and nationally at the presented at the 3rd Science and Technology Conference hosted by DWU in 2010. Her research interests are in the use of spreadsheets in mathematics education. Email: [tabady@dwu.ac.pg](mailto:tabady@dwu.ac.pg).