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Modern Ethnomathematics Mainstreaming through Enterpreneurship Using Mathematical Ornaments

Hanna Arini Parhusip, Hindriyanto Dwi Purnomo, Didit Budi Nugroho, Istiarsi Saptuti Sri Sri Kawuryan
Universitas Kristen Satya Wacana, Jl. Diponegoro 52-60 Salatiga - Indonesia 50711
e-mail: hanna.parhusip@uksw.edu

Abstract

Modern ethnomathematics is proposed in this article by introducing curves and surfaces to objects based on commonly used mathematics. There are 2 types of objects, batik and ornament. The object is known as Batima, which means a mathematical motif made in a batik stamp. The same design can be used to design ornaments, souvenirs, accessories or other household items such as glasses, t-shirts and other materials. The formation of ethnomathematics is driven by entrepreneurial activities. The method starts with the expansion of the circular and spherical equations based on the variation of the power form which was originally 2 in the equation to be valued at random (say p). The other used equations are parametric equations, especially the hypocycloid which is extended to both curves and surfaces with spherical coordinates. In addition, derivative operators can be applied. Product manufacturing is carried out by at least 10 household businesses around Salatiga and Jogjakarta and its surroundings. In order to sustain the mainstreaming of modern ethnomathematics, entrepreneurial activities are carried out with existing materials through exhibitions and competitions that are followed. Likewise, the use of social media and marketplaces are explored to mainstream the modern ethnomathematics into society.

Keywords: Ethnomathematics, Entrepreneurship, Parametric equations, Spherical coordinates, Hypocycloid

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INTRODUCTION

Learning mathematics can be from many different perpectives simultaneously to engage students in a learning process. This statement has been reported where possible variation in learning was analysized (Kullberg et al., 2017). In ethnomathematics particularly, this is obviously pointed out. One example is shown in the Arfak tribal communities where many different geometrical objects revealed (Haryanto et al., 2016) which related to studied mathematical topic at that time. Other example is obtaining mathematical expression in the special place such as in Kraton Jogjakarta (Mauluah & Marsigt, 2019) where almost all surroundings present mathematical terms to be material study for mathematics elementary school.

In these literatures, authors collect objects and specify mathematical terms on the objects leading to better understanding for students in the related topics in learning mathematics. Additionally, students learn cultures presented by the objects. Since cultures take place as part of the study, the idea of ethnomathematics is then introduced by integrating existing culture with existing mathematics studied in the research proposed in this article. The novelty of this approach appears by combining local culture, mathematical topics in creating curves and surves, and entrepreneurship skill.

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The special local culture addresses here is batik produced locally from Salatiga, Solo and Jogjakarta with mathematical motifs. The research has been going on and the result is called Batima (Batik Innovation of Mathematics) where algebraic surfaces was used (Parhusip, 2018). The other approach for mainstreaming ethnomathematics in this direction is creating mathematical objects called Odema (Ornament Decorative Mathematics). Students involve in designing the motifs, communicating to home industries to produce into objects and batiks, and trying to promote for society. These activities are integrated in learning mathematics for undergraduate mathematics students.

The research on usefulness of mathematics to entrepreneurship activities has confirmed that knowledge in mathematics may give success in entrepreneurship (Haara, 2018). Mathematics improves computational skill for the manufacture products, immense value in ensuring cost effective establishment and cost effective manufacture of various items, problem solving skill; innovative skill; analytical and creativity skill including decision making (Olukemi & Gbenga, 2016; Baiduri et al., 2020). Therefore, the entrepreneurship skill in mathematics students developed here by producing mathematical ornaments based on the knowledge mathematics that have been learnt and innovated into various objects where later on the products are mainstreamed through exhibition and promotion. Hence, the ethonomathematics here presents by creating designs based on mathematics, emerging into local culture such batik and other usual objects.

Furthermore, students are learning to entrepreneur the products to realize mathematics for costumers. We expect, modern ethnomathematics is realisticly learnt by these activities where students are learning on mathematical topics through designing, producing and promoting to society.

RESEARCH METHOD

Students must find their own competencies in mathematics in order to have their own innovation for creating curves and surfaces. Usually, students learn calculus containing many curves governed by functions in cartesian and polar coordinates. Started from this knowledge, students are visualizing many functions and trying to find new perpectives from the obtained curves and surfaces. Visualization of curves and surfaces for teaching calculus is necessary for having geometrical understanding (Baiduri et al., 2020) . The visualization is easy for functions or equations defined on real domains . On the other hand , functions defined on complex domains must be treated carefully though the functions only 1 independent variable on a complex domain . Typical studied materials are only for particular domains , i.e. a line , a rectangle and a circle mapped by simple complex mapping. The study was continued by illustration of some complex mappings . Furthermore , domains of complex mappings are defined by parametric curves leading to some mathematical motifs (Suryaningsih et al., 2013). The motifs are 'animals like'and 'flower like' and collected into some ornaments of hypocycloid dance since the motifs are basically obtained by hypocycloid curve (Parhusip, 2014). The motifs are again explored into 3 dimensional surfaces . The mapping images are not shown here though some products are presented based on the method of complex mappings on hypocycloid curves. Several learning procedures are proposed here.

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Designing curves and surfaces from circle and spherical coordinates

Undergraduate students are expected that students have learnt the wellknown curve and surface such as a circle, a sphere that are presented in Cartesian coordinates, polar coordinates and parametric coordinates. The equation describes a circle in Cartesian coordinate for p=2. In particular, an astroid can be obtained for p=2/3. Rectangular representation of astroid is and its parametric is in the form and . For a general class of p, this is not yet published elsewhere which is the interest of this part in this paper.

We have known that the parametric equation for a circle is and with center O(0,0) and its radius r or , for p=2 in the Cartesian coordinates . Let us consider :

; . (1)

The equation (1) can be written into . For p=1,2 and 2/3, the geometrical curves are known, i.e. a line, a circle and an astroid respectively. Thus we have generalized the equation into parametric equation in Eq.(1).

One may observe that the solution pair of (x,y) for can be complex numbers for a real value of r. Therefore, it is convenient to write as

, and . (2)

In other words, the Eq.(2) leads to the problem : find on a complex plane such that Eq.(2) is satisfied. For a geometrical purpose, the interest here is the geometrical part of real parts of .Thus the innovative curves are satisfying (2).

The second studied geometrical surface is a generalization of sphere, i.e.

. (3)

This equation gives us a sphere with center on O and its radius r for p=2. Furthermore, one may extend the Eq. (3) to be a three-dimensional astroid by using spherical coordinates, i.e.

. (4)

The illustration of the Eq.(4) is shown in Fig. (1).

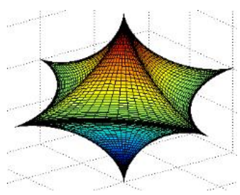

Figure 1. Ilustration of three dimensional astroid using spherical coordinates.

As in two-dimensional case, one may express Eq.(3) into parametric equations, i.e.

(5).

Since three-dimensional astroid can be defined, one generalizes Eq.(3) into Eq.(5) and try to find the appeared geometrical phenomena for different values of p. Thus, the surfaces given by Eq.(5) will be the real parts of solutions

(6)

Geometrical interpretation of

An interesting geometrical part of Eq.(1) is the family curves obtained by , the real part of each point (x,y) behaves similarly. One suggests that for , the geometric visualization of the solution is in one family of curves. Figure 2 describes all geometric visualization of Eq.(1) for p=1 ,2,3,4. Some different curves appear on this figure. We deduce to a conclusion that there exists no similarity pattern in these curves. On the other hand, Figure 3 depicts some similar curves for p=5,6,7,8. The additional observations lead to the same geometrical phenomenon for p=9,10,11,12 as shown in Figure 3. The family of curves is called weak kite in this paper. This is not yet known in other papers.

Figure 2. Geometrical visualization of Eq.(1) for p=1,2,3,and 4.

Figure 3. Geometrical visualization of Eq.(1) for p=5,6,7,and 8 (the real part of (x,y)). and for p=9,10,11,and 12. All curves are called weak kites.

All curves above drive to a general question, such as which values of p leading to similar curves. Since a special $p=2/3$ has been known as an astroid, one may research for any other fractional numbers in the form $k/3$ for any natural number of k with k >2. To give complete information, Figure 4-7 show the geometrical illustrations for each value of p.

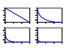

Figure 4. p=1,1/2 /, 1/3 and ¼

Figure 5. p=1/3,2/3/, 3/3 and 4/3.

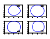
Figure 6. *p*=5/3, *p*=6/3, p=7/3 dan *p*=8/3 (the real part). The value of *r*=3 does not affect the geometrical performance. This is the family of weak circles.

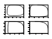
Figure 7. *p*=9/3, *p*=10/3, *p*=11/3 dan *4*=12/3 (the real part).The value of *r*=3 does not affect the geometrical performance. This is the family of weak circles.

One may predict that for *p=k*/3 with , Eq.(1) creates the family of curves, the same attitudes for arbitrary integer values of . Please verify by extending the domain of the axes, we have still a close curve as shown by Figure 8. By increasing the value of *p*, i.e. *p*=13/3, 14/3, 15/3, 16/3, the family of weak kites appears since all curves behave the same as Figure 2. This is shown by Figure 9. The observation is then continued.


Figure 8. Closed curve of a weak circle for *p*=4 or 12/3.


Figure 9. The family of weak kites for *p*=13/3,14/3 , 15/3,16/3

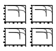
Figure 10. The family weak kites *for* *p*=25/3,26/3 , 27/3,28/3


Figure 11. The family of weak kites *for p*=29/3,30/3 , 31/3,32/3

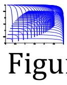
Figure 12. The family of weak kites for *p* *p*=13/3,..., 33/3

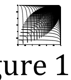
Figure 13. The family of weak kites for *p*=34/3,..., 100/3.

The observations lead to patterns of weak kites for p started from 13/3 up to 33/3. Processing up to p=100/3, similar patterns are obtained (shown by Figure 12-13).

Note that the solutions of can be complex numbers. Therefore the real part solutions of are concluded to be family of weak kites for $p=k/3$ with . One needs to prove more formally which is not shown here. As mentioned above, that the interest in this paper is the geometrical phenomenon of (Re z_1,Re z_2) satisfying .

Geometrical of

We extend the equation into three-dimensional shape as shown in the Eq.(6). Since p=2/3 has led to a known geometry, we try for $p=k/3$, k=1, 2,...,20. One observes for p=12,..., 20 the surfaces have the same families. The collections of surfaces are called parking surfaces. Some surfaces are shown in Figure 14.

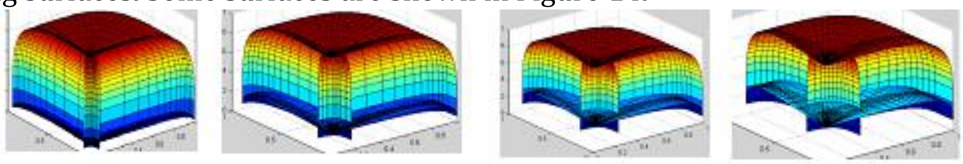

Figure 14. The family of parking surfaces for p=13/3,14//3,15/3/16/3 (from left to right)

Note that the two-dimensional projections have the same images as shown in Figure 9-13.

Some surfaces are found by varying the values of p. Started with astroid in three dimensional (p=2/3) and vary for $p=2/k$, k=4, 5, 6, 7, 8, 9, one observes geometrical patterns as depicted in Figure 15. Weak astroids are observed for p=2/3, 2/5, 2/7 and 2/9 with diminishing surfaces area. Generally, one may have weak astroids for $p=2/(2n+1)$, for n is natural number.

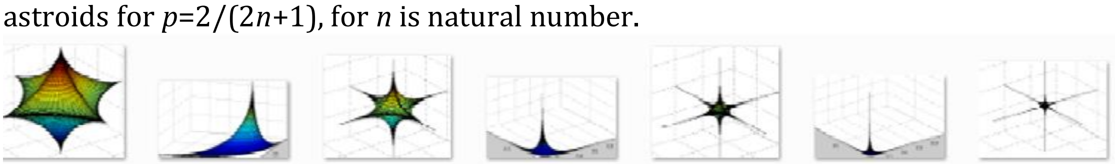

Figure 15. Visualization of , p=2/3, 2/4, 2/5, 2/6, 2/7, 2/8, 2/9 (from left to right).

As we notice, real solutions have closed astroid surfaces with decreasing area of surfaces for p=2/3, p/5, p/7. On the other hand the open surfaces are found for p=2/4, 2/6, 2/8. One may increase the value of denominator and we have the area of surfaces tends to zero for all p.

Some variations of parameters have been observed in the results of surfaces where the value of , k=1,2,3,...,15.

For irrational numbers of p some interesting patterns of surfaces are found. One observes that families of surfaces are started from . Closed surfaces called weak astroids are obtained for , , and with each area is diminishing. Otherwise, for , , , , , , the open surfaces are shown with similar pattern. The surfaces are shown in Figure 16-19.

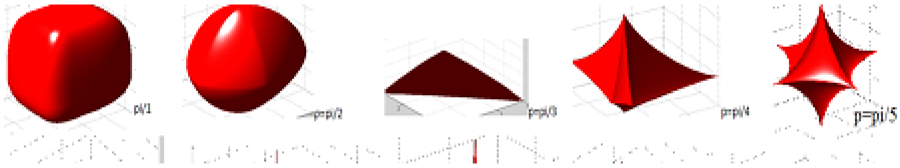

Figure 16. The family of surfaces obtaining from , k=1,2,3,4,5

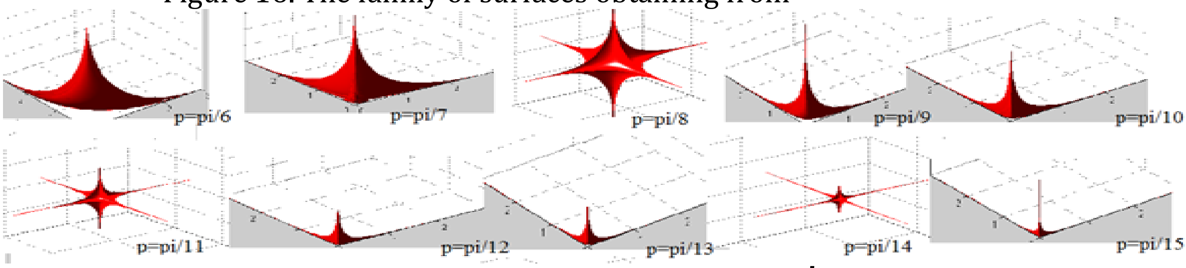

Figure 17. The family of surfaces obtaining from , k=6,7,...,15

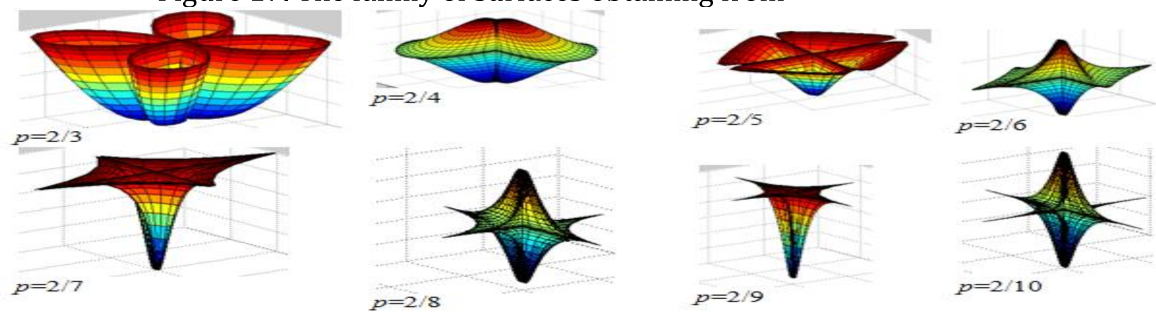

Figure 18. Collections surfaces of $\left(\overline{d\theta}, \overline{d\theta}, \overline{d\varphi}\right)$,p=2/k, k=3,4,...,10

By studying the surfaces created by the derivatives, open surfaces are obtained for p=2/k, k is an odd number and closed surfaces for p=2/t where t is an event number (see Fig. 18). As above, the areas of surfaces are decreasing for increasing values of k and t. These surfaces are possible to be some mathematical ornaments. At least, 10 home industries have involved in creating ornaments and some usable objects such as bags, souvenirs, accessories above.

Designing curve and surfaces from hypocycloid curve

Students in calculus have learnt parametric curve and one of them is called hypocycloid curve. By generalizing the hypocycloid curve into pseudo polygon in terms of discretization , several new curves obtaine (Parhusip , 2020). This paper proposes its generalization to be three dimensional surfaces where detail idea has been explained on the other literatures, i.e. (Parhusip et al., 2020).

$$x = \sin\phi\left((a-b)\cos\theta + b\cos\left(\left(\frac{a-b}{b}\right)\theta\right)\right);$$
$$y = \sin\phi\left((a-b)\sin\theta - b\sin\left(\left(\frac{a-b}{b}\right)\theta\right)\right); \quad (6)$$

$$(7)$$

where $\sin\phi$ This generalization is defined by using spherical coordinates.

All generalization above still can be innovated by presenting of each derivative to create the new curves and surfaces improving ethnomathematics materials to be products. Note that the derivatives of the equations may create other curve and surfaces. In 3 dimensional case (see Eq.5), we may have some possible triple to visualize the surfaces due to the derivatives, i.e. $\partial\rho$ and . Since =0 for the Eq.(5), the number of possible surfaces are =56 . Furthermore, the second derivatives may be created.

RESULTS AND DISCUSSION

Demonstration of Ornament Decorative of Mathematics

The formula of Eq.(5) leads to design mathematical objects for various values of *p*. Some innovations to be ornaments are designed by hypocycloid curves generalized into three-dimensional objects as shown in Introduction. These ornaments contain some mathematical art, accessories, motifs on bags, motifs on glasses which are shown on the Figures 19-25 to be products of modern ethnomathematics. All designs and products are named to make easily identified for the next purposes,e.g. updating design, coding into product and promoting to customers. One copyright obtained in this activity in 2015 called Spider Cos as a claim motif art. Therefore based on this copyright, some ornaments are produced.

Figure 19. Twin Cups, generalization of spheres (Week spheres)

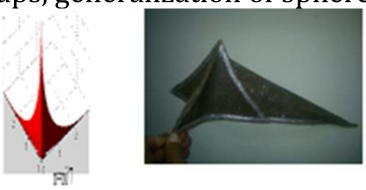

Figure 20. Design (left) and its ornament (right) of for

Figure 21. Souvenir of Spider Cos motif made by copper (left) and the motif Spider Cos is used to design a bros as a decoration of cloth (right)

Figure 22. Some motifs (left) designed based on parametric curves and complex mappings and the products on hair decoration, cloth decoration, bags and glasses for mainstreaming modern ethnomathematics to society.

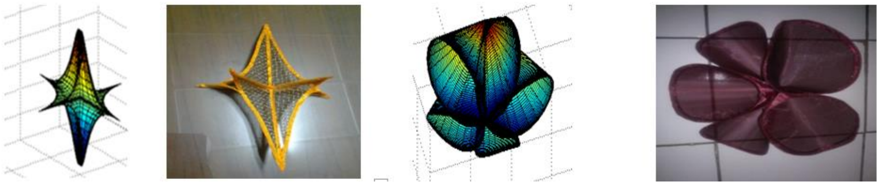

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Figure 23. Designs and Surfaces of $\left(\frac{}{d\theta},\frac{}{d\theta},\frac{}{d\varphi}\right)$, for p=2/8=1/4 (left) and $\left(\frac{}{d\theta},\frac{}{d\theta},\frac{}{d\varphi}\right)$ of 3d Hypocycloid with a=5;b=1 (right)

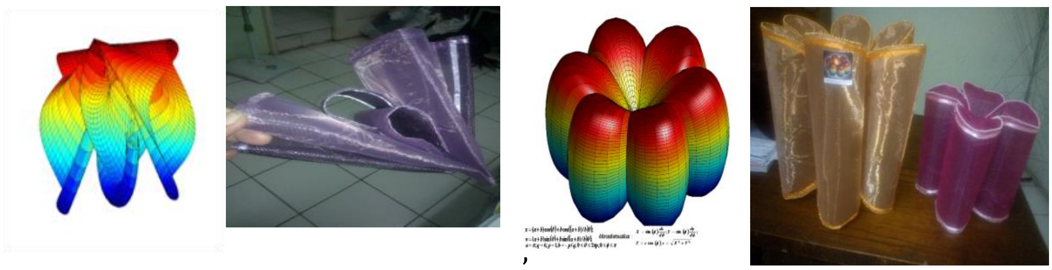

Figure 24. Design and its Surface of $\left(\frac{}{d\theta},\frac{}{d\theta},\frac{}{d\varphi}\right)$ of 3d Hypocycloid :for' p=1;q=4; a=1;b=-(p/q) (first pair,left) . Derivative of hypocycloid for p=1;q=6; a=1;b=-(p/q) (second pair, right).

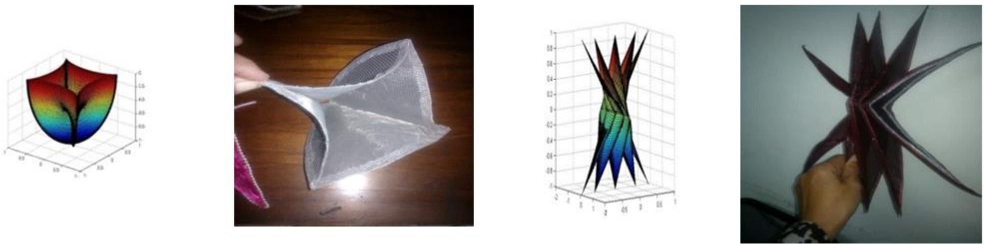

Figure 25. Design and its surface of Derivative of hypocycloid $\left(\frac{}{d\varphi},\frac{}{d\varphi},\frac{}{d\varphi}\right)$ p=1;q=4;a=1;b=-(p/q) (first pair, left) and Design and its surface of Derivative of hypocycloid $\left(\frac{}{d\theta},\frac{}{d\phi},\right.$ p=1;q=4;a=1;b=-(p/q) (second pair, right)

Modern ethnomathematics mainstreaming through Exhibition and Competition

In order to be acknowledged by public, designs and products above are mainstreamed through some promotion, exhibitions, competition. Using objects mentioned above, the promotion was done firstly in November 2013 in TV Pro as local TV in Central Java. After this activity, promotion was continued in the Conference Hall of Universitas Kristen Satya Wacana (UKSW) in Science Festival November 2013 presented as a dance (visit youtube using a keyword : Hypocycloid Dance in youtube) where all ornaments used by dancers were designed by mathematical formulas and made by home industries. The other activity was a poster presentation in international Congress for Mathematician (ICM),August 13-21, 2014 Seoul, South Korea). Some ornaments were developed and promoted in October 2014 for an Open House of FSM shown in Fig. 26. Mainstreaming through an individual exhibition has been organized in Rumah Noto (SWCU) , 3-4 February 2015 where about 200 students from senior high schools and undergraduate students from UKSW have visited the expo. Some photos are depicted in Fig.27-33.

Figure 27. Mainstreaming with open house FSM-October 2014

Figure 28. Mainstreaming with 'Expo Math' 2-3 Maret 2015 (Rumah Noto, SWCU, Salatiga, Indonesia).

Figure 29. Mainstreaming with individual 'Expo Math' 2-3 Maret 2015 section Math-Art.

The exhibition was again organized to promote mathematics in the 1st August 2015 in the event of International Conference of Science and Science Education in Salatiga, Central Java. Students from a school also involved for creating mathematical objects shown in Fig. 30. A pattern obtained from complex mapping from a hypocycloid curve was used to design puzzles and a child dress as shown in Fig. 30-33.

Figure 30. Puzzle math by students from Senior High School (SMA N2 Salatiga, Indonesia, July 2015).

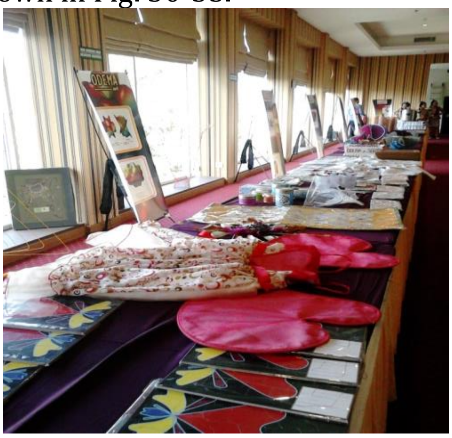

Figure 31. Mainstreaming with individual exhibition ,1st August 2015 in IConSSE organized by Science and Mathematics Faculty, SWCU, Indonesia in Laras Asri Hotel).

Mainstreaming through a competition had also been attended organized by local city government of Salatiga which based on the creation and innovation in the researches. The competition was called Krenova and the competed products was named ODEMA-Art. The third winner was achieved and announced on 11st December 2014. In June 2015, Krenova Competition Province Central Java was also attended. Finally, the ODEMA Art was one of the runners up among 10 runners up from the 27 competitors from Province Central Java selected from 77 participants declared in 17 September 2015. In order to mainstream modern ethnomathematics, the ODEMA Art was also exhibited in 24-26 October 2015 among all innovators from Central Java province in Indonesia which was organized by Central Java government called Balitbang. Some photos are shown in Fig. 32.

Figure 32. Mainstreaming modern ethnomathematics with ODEMA Art exhibition in Semarang, 24-26 October 2015 organized by Balitbang (goverment in Central Java, Research and Innovation sector).

As we have learnt from above, that mainstreaming modern ethnomathematics has been done in last 8 years. In 2016, one of the products was introduced to be product of innovation in Indonesia mentioned by Business Indonesian Center (BIC) named Batima (Batik Innovation of Mathematics). Activity of entrepreneurship skill was developed where students organized a workshop for middle school students to learn how the products were designed in June 2017 and collected into some learning process for visualization in modern ethnomathematics where batik and ornaments were mathematical based (Parhusip & Susanto, 2018). Until 2019, many exhibitions have been organized where the mathematics entrepreneurships were delivered automatically by these activities integrated through lecturing for undergraduate students and promoting the idea for wider students , teachers including society in a village called Dusun Sawit. Readers may address the youtube below for more details informations shown by Fig. 33-35.

Figure 33. Community service at 18 March 2018 in Sawit village, Semarang District
Source https://www.youtube.com/watch?v=od89kDtvz10

Figure 34. Community service for middle school in Johor Baru,Malaysia, October 2019
Source https://www.youtube.com/watch?v=CPiAJi0FIa4

Figure 35. Visiting lecturer in UTM October 2019 :
Source: https://www.youtube.com/watch?v=qXmciclim1c

Finally, in the year 2020/2021, Indonesian government has added funding to UKSW from community service grant called PPUPIK related to this project for mainstreaming the materials into more soldable and useable to society. Many more products are shown in the youtube channel shown in Fig. 36.

Social media such as instagram,facebook and twitter are mainstreaming the modern ethnomathematics in this direction and the market place such as shopee, tokopedia are also used. One may address garisma2020 in instagram, facebook and website and the marketplace to mimic more clearly.

Figure 40. Some of the products collection,
https://www.youtube.com/watch?v=52ZDLQ_fEZA.

Copyrights are registered

Some innovations have been registered as copyrights nationally. Initially, there are 2 simple patents called Spider Cos and Rocket Math in the year 2015-2016. After government agreed to fund the activities above, in the year 2016-2017, there are more improvement on designs and products including the obtained copyrights. In the year 2020, there were 5 copyrights obtained in the entrepreneur activity in the university based on the obtained designs where undergraduate students also as part of the owners of these copyrights.

Finally, we summarize that the modern ethnomathematics proposed here has shown different aspects of learning particularmathematics such as curves and surfaces integrated with existed local cultures and modern aspects in promoting by entrepreneurship activity. This activity leads to varies study in mathematics. Referring to other author in varies theory of learning mathematics (Kullberg et al, 2017), the paper here is direct practice of the theory that several aspects are integrated.

Additionally, the modern integration study of mathematics in this direction can be viewed as STEAM education where mathematics,art and technology in small scale should be learnt simultaneously (Kang, 2019).

CONCLUSION

This article proposes modern ethnomathematics mainstreaming through designs and the related products which are usually used by people. The development of designs was started from the known curves by students in calculus, namely circle and sphere. Students are also learning parametric curves including hypocycloid curve as the particular example shown in this article. By reinventing the exponent in circle and sphere equations, new curves and surfaces were obtained. Additionally, the hypocycloid equation was usually known only presenting curves. The research here has shown that many surfaces can be defined using spherical coordinates.

In this paper, some innovations on curves and surfaces are obtained by generalizing parametric curves into modern ethnomathematics surfaces. The obtained curves are presented into some objects such as souvenirs, accessories, and puzzles. The curves surfaces are defined into mathematical ornaments. The mathematical operators such as derivatives, complex mappings for parametric curves were employed to have innovations on curves and surfaces to be materials for entrepreneurship activity. The mainstreaming modern ethnomathematics activities are exhibition and promotion using the obtained products named as Batima and Odema. The development of research can be continoued by promoting more massively such that any society easily recognizes Batima and Odema in all around.

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