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MATHEMATICAL SILVER FOR ENTREPRENEURIAL MATHEMATICS

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Abstract. *This article shows the result of entrepreneur mathematics by creating mathematical objects from silver. The objects discussed here are accessories to introduce undergraduate students to integrating several aspects of learning mathematics. These are learning geometry modernly, mathematical art, popularizing mathematics for society, introducing entrepreneurial values using mathematics, teamwork for achieving targets, and considering local heritage in mathematics. These aspects are blended into activity by creating designs and producing products based on the obtained designs. The particular product for this activity is creating silver accessories. The used research method is initiated by creating designs with the help of software where the surface equations are known. After the designs are obtained, the designs are communicated to the silver craftsman to be a partner in design testing and manufacturing of accessories products using the given designs. The size and the similarity of perceptions to the appearance of the design are discussed because the actual design is a three-dimensional image but expressed in objects to be two- dimensional objects. After productions are obtained, the accessories are managed to be promoted to the marketplace and social media as a form of entrepreneurial activity with materials starting from mathematics*.
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Keywords: *algebraic surfaces, designs, entrepreneur, popularizing mathematics, silver.*

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1. INTRODUCTION

Mathematics is still a study field that is considered difficult and unattractive by many people generally [1]. Mathematical innovation research is needed to overcome the gaps in the use of mathematics in various fields from an early age both in society and in education. On the other hand, people believe that mathematics is useful. Therefore, an integrated way of learning is necessary where the traditional approach of learning is not appropriate, i.e. students should learn in a modern way by using technology, creating material and combining art with it, and popularizing it in the public. The famous technique in learning is called STEAM (Science, Technology, Engineering, Art, and Mathematics). These topics are blended into a particular study which improves students' understanding and literacy in several aspects of learning simultaneously. One way is introducing mathematics literary by using ICT (information and communication technologies) [2]. ICT is used to visualize mathematical expressions [3] which are mostly needed for geometrical illustration. The Readiness of Arab teachers in Israel was studied for using ICT in the classroom [4], yielding better understanding for students. Additionally, learning geometry is addressed to be highly concern by several authors to improve students' literacy in geometry[5] [6][7]. The other effort is introducing mathematics for entrepreneurship.

Introducing mathematics for entrepreneurship is very rare and known to the public through an old effort that had existed in the literature to overview this case [8]. One may refer to this literature[9] that students in Latvia developed entrepreneurial competencies among Latvian students in mathematics and science subjects. Nigeria however, for years had sought to find out the relevance of mathematics to entrepreneurship skills acquisition by 200 pre-service teachers selected from three colleges of Education in Lagos, Nigeria [10]. Similar activities are found, e.g. entrepreneur skill was developed for 8 students in primary school in Swedish [11] and based on the relationship between pedagogical entrepreneurship in mathematics and mathematical literacy in the literature [12]. Additionally, awareness of entrepreneurship skills acquisition has been considered to be an institutional concern in Colombia [13]. Therefore, addressing entrepreneurship with mathematics is highlighted in this article.

Thus the article shows how students learn several aspects of the learning process through creating designs from the mathematical topic such as algebraic surfaces and popularizing objects which have economic values. The method above is carried out more massively by involving various partners and social media to reach the community more easily so that the gap mentioned above can be reduced. For this reason, this article shows the use of software (namely Surfer and Mathmod), to become ornament designs in the form of accessories for entrepreneurship activities.

2. RESEARCH METHODS

2.1 Design Development

This research activity is characterized by creating basic designs for making accessories where the main design uses an algebraic surface with the help of Surfer software and Mathmod. By analyzing each design based on its aesthetic value, the design is then tested to produce to be a product. Designs have been done with various mathematical formulas, to produce an ornament called ODEMA and a batik motif called BATIMA in the last 7 years. The following steps are a collection of general steps that have been taken to get the ornament including accessories and batik produced.

2.1.1 Group Design A

Designs with parametric curves mapped complex functions as well as with various other mathematical operators. The procedures contain the following information:

(i) Starting from the creation of a parametric curve, namely a modified hypocycloid curve [14] mapped with complex functions.

(ii) Using the differential operator in step (i) to obtain the variation curves [15].

(iii) Using spherical coordinate transformations to bring the resulting curve to a surface.

(iv) Apply a differential operator to step (iii) to obtain a new surface.

(v) Using the Fibonacci sequence to get the surface variation from (iv).

(vi) Varying the existing parameters on the parametric curve in steps (i) - (v) to be able to find new shapes that are used as designs.

However, this group is not widely used in this study but is used as a reference and comparison of existing products with those made in this period. The use of parametric equations as two-dimensional ornaments was carried out by using discretization in the extended hypocycloid equation so that it becomes a pseudo polygon pattern as a form of curve stitching [15].

2.1.2 Group design B

Design is obtained from Surfer software. Using Surfer software to get an algebraic surface as a new surface for the basic ODEMA and BATIMA designs. The algebraic surface that already exists in Surfer has varied equations so that the resulting surface becomes the basic shape for the accessories. The selected design are communicated to the crafts for production.

2.1.3 Group design C

Designs are obtained from other software as a comparison to obtain more varied creativity. The used software for example is called Mathmod.

The existence of a surface with a known formula is characteristic of the used method where the surface is the basic form of the design which can then be varied in various ways where a three-dimensional surface becomes a two-dimensional appearance.

2.2 Promotion activity

Promotion is needed for communicating the products to the public and to reach potential customers. For mathematics students, the skill for doing promotion should be developed which is mainly not the interest of the students. Therefore several technics in promotion must be developed such as push strategy and attract strategy through active and passive promotion [16]. It is expected that an appropriate promotion will improve awareness [17].

3. RESULTS AND DISCUSSION

3.1 Results Design

In this section, we show the design results obtained with the Surfer and Mathmod which are only partially shown in the obtained many designs. Each design is given a name. Because the formulation is not recognized by the general public, the description of the motive is explained so that it replaces the formulation so that it can be easily accepted by readers in copyright submissions. Following the used software notions, one of the formulas is written as:

$$4a\left(\left(a\frac{1+\sqrt{5}}{2}\right)^2 x^2 - y^2\right)\left(\left(a\frac{1+\sqrt{5}}{2}\right)^2 y^2 - z^2\right)\left(\left(a\frac{1+\sqrt{5}}{2}\right)^2 z^2 - x^2\right) - a\left(1+2\left(a\frac{1+\sqrt{5}}{2}\right)\right)(x^2+y^2+z^2-1)^2 = 0 \quad (1)$$

Using the Surfer software, the formula (1) must be rewritten as:
$(4 * ((a * (1 + sqrt(5))/2)\text{^}2 * x\text{^}2 - y\text{^}2) * ((a * (1 + sqrt(5))/2)\text{^}2 * y\text{^}2 - z\text{^}2) * ((a * (1 + sqrt(5))/2)\text{^}2 * z\text{^}2 - x\text{^}2) - (1 + 2 * (a * (1 + sqrt(5))/2)) * (x\text{^}2 + y\text{^}2 + z\text{^}2 - 1)\text{^}2) * a = 0.$

Figure 1. The 4C-Generation motif is given by Equation (1), designed using Surfer

The resulting motif is shown in Figure 2 and called as 4C-Generation. Another design is obtained similarly. Another design is called Sun's Fire. Sun's Fire is a form of mathematical ornament made with an algebraic surface design. The design obtained (can be seen in Figure 1) is a 3-dimensional surface where the design results to get a 2-dimensional shape called Sun's Fire. The equation is shown here:

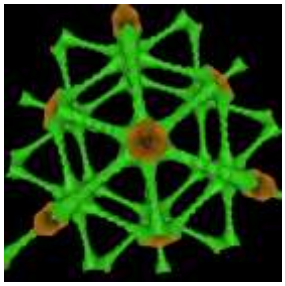
$$z - a\left(-\frac{1}{4}\left(1-\sqrt{2}\right)\right)(x^2+y^2)^2 + (x^2+y^2)\left(\left(1-\sqrt{2}\right)z^2 + \frac{1}{7}\left(2-7\sqrt{2}\right)\right)z^4 + \left(\frac{1}{2}+\sqrt{2}\right)z^2 - \frac{1}{16}(1-12\sqrt{2}))\text{^}2 - \left(\prod_{i=0}^{7}\cos(i\pi/4)x + \sin(i\pi/4)y - 1\right) - z = 0. \quad (2)$$

Similarly, one writes using Surfer as

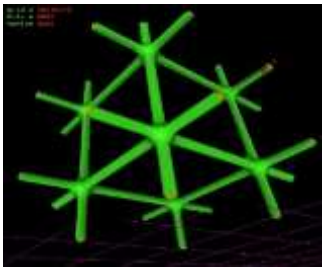
```
z-a*(-1/4*(1-sqrt(2))*(x^2+y^2)^2+(x^2+y^2)*((1-sqrt(2))*z^2+1/7*(2-7*sqrt(2)))
z^4+(0.5+sqrt(2))*z^2-
1/16*(1-12*sqrt(2)))^2-(cos(0*3.14/4)*x+sin(0*3.14/4)*y-1)*(cos(3.14/4)*x+sin(3.14/4)*y-1)*
(cos(2*3.14/4)*x+sin(2*3.14/4)*y-1)*(cos(3*3.14/4)*x+sin(3*3.14/4)*y-
1)*(cos(4*3.14/4)*x+sin(4*3.14/4)*y-
1)*(cos(5*3.14/4)*x+sin(5*3.14/4)*y-1)*(cos(6*3.14/4)*x+sin(6*3.14/4)*y-
1)*(cos(7*3.14/4)*x+sin(7*3.14/4)*y-1)-z = 0.
```

Figure 2. Motif Sun's Fire

Other designs here are named as DB-Hexagon and Dancing Bamboo which are shown in Figures 3(a) and 3(b) The designs are then selected to become several products. There are many more designs that can be created. The other algebraic surface used in the product is also shown here in Figure 3(c) Finally, we can use the designs in products.



(a)



(b)

Figure 3. (a) Model DB Hexagon (left) and (b). Dancing Bamboo (right) taken from MathMod

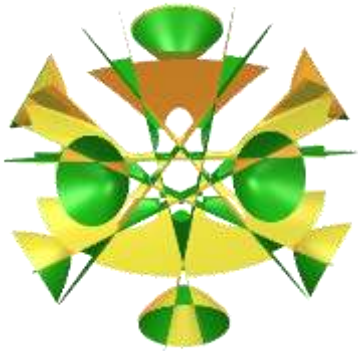


Figure 3(c). Model made from Surfer

The equation for Figure 3.c is given by Surfer as:

a*0.99*(64*(0.5*z)^7-112*(0.5*z)^5+56*(0.5*z)^3-7*(0.5*z)-1)+(0.7818314825-0.3765101982*y-0.7818314825*x)*(0.7818314824-0.8460107361*y-0.1930964297*x)*(0.7818314825-0.6784479340*y+0.5410441731*x)*(0.7818314825+0.8677674789*x)*(0.7818314824+0.6784479339*y+0.541044172*x)*(0.7818314824+0.8460107358*y-0.193096429*x)*(0.7818314821+0.3765101990*y-0.781831483*x)*(((a*(1+sqrt(7))/2)^2*x^2-y^2)*((a*(1+sqrt(7))/2)^2*y^2-z^2)*((a*(1+sqrt(7))/2)^2*z^2-x^2)-1*(1+2*(a*(1+sqrt(7))/2))*(x^2+y^2+z^2-1)^2)* a*(-1/4*(1-sqrt(2))*(x^3+y^2)^2+(x^3+y^2)*((1-1/sqrt(2))*z^2+1/8*(2-7*sqrt(2)))-z^4+(0.5+sqrt(2))*z^2-1/16*(1-12*sqrt(2)))^2-(cos(0*3.14159265358979/4)*x+sin(0*3.14159265358979/4)*y-1)*(cos(3.14159265358979/4)*x+sin(3.14159265358979/4)*y-1)*(cos(2*3.14159265358979/4)*x+sin(2*3.14159265358979/4)*y-1)*(cos(3*3.14159265358979/4)*x+sin(3*3.14159265358979/4)*y-1)*(cos(4*3.14159265358979/4)*x+sin(4*3.14159265358979/4)*y-1)*(cos(5*3.14159265358979/4)*x+sin(5*3.14159265358979/4)*y-1)*(cos(6*3.14159265358979/4)*x+sin(6*3.14159265358979/4)*y-1)*(cos(7*3.14159265358979/4)*x+sin(7*3.14159265358979/4)*y-1)

where a = 0.38 , zoom = 0.11 x .

3.2 Products designed into accessories

Several designs are selected to be the basis for the products. For example, the resulting product is a key chain shown in Figure 4. To be marketable products, students are encouraged to work with home industries around the city.

Figure 4. Two samples of key chains using the obtained designs

The products are also expected to give economic value. Another educative aspect to integrate for students is considering local heritage that has not been dealt with in the activity. Students decided to produce the designs into silver accessories. Therefore some products in Figure 5 below are collections of accessories made from silvers. Some of the above designs have been copyrighted with the list shown in Table 1.

Table 1. List of copyrights obtained from design activities

No. Copyright No. Submission and filed on October 23, 2020	Copyright name	Type of copyright
EC002020434852020; Regristration Number : 000216531	Dancing Bamboo	Motif Art
EC00202043484, Registration Number : 000216530	4C Generation	Motif Art
EC00202043482, Registration Number : 000216529	Ten FD-Cone	Motif Art
EC00202043486 Registration Number : 000216550	DB Hexagon	Motif Art
EC00202043111, Registration Number : 000216922	Sun's Fire	Applied Art

Sun's Fire 4C-Generation

DB Hexagon Dancing Bamboo

Figure 5. Sets of accessories made by silvers craftsmen

The obtained designs are not only for accessories that are classified as ODEMA (Ornament Decorative of Mathematics) but also for batik motif designs which are called BATIMA (Batik Innovation of Mathematics). Product preparation activities are carried out to be promoted so that entrepreneurial activities with the results of these products can be recognized by the public by using various social media, namely the web, videos on YouTube, Instagram, and Facebook. Meanwhile, product sales use marketplaces such as Tokopedia and Shopee. For promotion and marketing, supportive media are needed. In addition, a store name is required as a place to provide products. In this activity, the shop is called CARISMA which stands for Gallery Research of Innovation Mathematics.

3.2 Learning mathematical promotion and entrepreneurial skills

As stated in the introduction that mathematics is considered to be unattractive by many people. After creating the designs into products, the products should be known by the public. Students have made products that should be acknowledged by society which can be easily done by using the internet and social media. Therefore, the next activity is promoting products. Before this activity, students must record each piece of product on a database such as collecting photos, naming products and designs, pricing each item, coding and labeling each item, and clustering the types. After these, students may use the available platform on the internet. For instance, by creating the web, students learn to collect the products into readable information

for the public. In the first exercise, students used the Wix platform as shown in Figure 8. The web was created with the aim of promotional media both nationally and internationally. However, until this research was written, the web is still in the process of being made.

Figure 6. Web illustration on the new preferred Wix Web platform www.garisma.com.

Since students are also learning entrepreneurial skills, students take Shopee for marketing under the name Garisma2020 as shown in the following Figure 7.

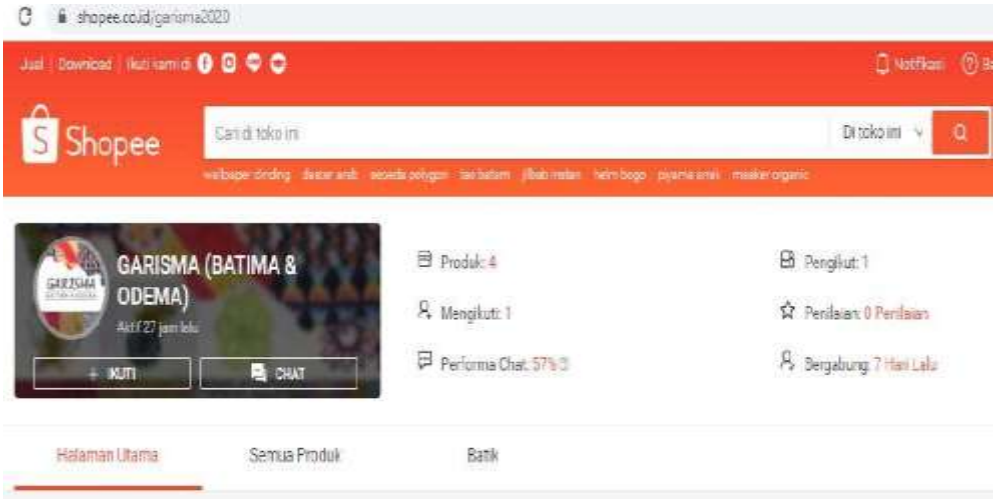


Figure 7. Shopee front illustration

Additional social media is Instagram which is normally familiar to the young generation. Therefore Instagram is also used as a promotional tool with the name Instagram: garisma2020. Finally, students should also document the products in a promotional video. One video has been created on youtube as illustrated in Figure 8.

Figure 8. The promotional video for the product that has been made is shared on youtube https://www.youtube.com/watch?v=52ZDLQ_fEZA.

Videos were also made in the context of participating in competitions held by International Day of Mathematics (DM) in March 2020 where the IDM 2020 event falls on March 14, 2020. The video results are shown on the link: http: // www.youtube. com/watch? v = hn9OjLyHzGA.

3.3 Promotion with attending a competition

In July 2021 students from undergraduate mathematics was attending the competition called Krenova in Salatiga city, central Java. The results on accessories from silver were considered to be the material. Finally in August 2021, the students won as the second winner in that competition. This activity was one of promotion materials such that the product in entrepreneurship of mathematics is known more publicly.

4. CONCLUSIONS

This article has shown the learning process of undergraduate students by integrating several aspects of learning mathematics. By creating mathematical designs into silver accessories, students require to learn geometry, mathematical art, teamwork, and entrepreneurial skill. Several methods for creating the designs are used. Initially, the research was mapping complex functions to parametric equations. Then the parametric equation is specific to the hypocycloid curve which contains 2 parameters so that its use can be expanded. Also, with a spherical coordinate equation, an equation that is just a curve equation becomes a surface. With the presence of surface formation, creativity is still needed in the surface making. Therefore authors use Surfer to increase creativity. A particular mathematical topic is learning algebraic surfaces. The designs obtained by algebraic surfaces are produced into several products such as silver accessories as the main products through other products are also possible. In the final learning process, students should develop entrepreneurship activities. Social media such as Instagram, Facebook, and the marketplace are used to promote the products. Thus, the research here has shown students' activities in blended learning of mathematics for several aspects to improve student competencies simultaneously. Students provide mathematical innovation and creations achieving products that can be used easily. In addition, the obtained product must have economic value so that it involves many partners in the manufacturing process. The particular products in this research are silver accessories which are also local culture. Activities in making mathematical ornaments in the form of accessories need to be expanded and further promoted so that designs from mathematics can be used by craftsmen in increasing the innovation and creativity of the products they produce. Meanwhile, further research can be carried out by developing the obtained designs.

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