Learning mathematics through art in a faculty of engineering

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ABSTRACT: The Covid pandemic has caused that learning activities had to be shifted on-line across most universities, in Indonesia, including the Faculty of Engineering at Maranatha Christian University, Bandung. Over the years, engineering courses at this University have not included any content aimed at developing emotional and humanistic values, much needed in future practice. One of the solutions adopted is an art learning programme combined with mathematics, where students create a batik motif with a turtle graphics algorithm in the Python language. The objective is to develop humanistic values in students. To test the effectiveness of this approach, a questionnaire was distributed to 126 students, of which 74% were male, and 26% female students. The findings indicate that 55% of the students are interested in learning art and in the turtle graphics training to create a *batik* motif. The conclusions are: 1) the creative functioning of the brain can be improved through learning with batik motifs; 2) respondents who learn through making batik motifs interact better in their social environment; and 3) the ability to make batik motifs can be assessed from the shape, proportion and the scale of the created motif.

INTRODUCTION

Since the pandemic, the delivery of education in Indonesia has changed from mostly on-campus to on-line learning. In view of this shift, new learning strategies had to be employed to ensure that the quality of educational outcomes and students' competence are maintained or improved. A study by Pusca and Northwood [1], provides an interesting insight into the impact of positive change on undergraduate students' learning in an engineering department. The authors stress the importance of staging the learning process starting with initiation, implementation and continuous improvement.

Over the years, it has been emphasised that engineering students require direct practice in the relevant industry sector, because this will give them the practical skills needed by the industry. A case study shows that direct practice can positively impact on the development of knowledge and skills in both the cognitive and affective domains, such as design, creativity, communication, modelling and teamwork [2].

The output-based education has been discussed by Pusca and Northwood [3]. In their research, students are involved in blended learning activities, and this approach is successful as it gives better learning outcomes that fit the target. Most first-year students do not understand engineering graphics, have insufficient visual competence, and are not used to the design process in engineering. This can be improved by including visualisation techniques, sketches, isometric drawings and orthographic projection in their learning. Each team consists of 5-7 students, and the final outcome is communicated by using a graphic communication technique [3].

In the 21st Century, graduates are faced with increasingly more complex work-based problems that they must be able to solve. The ability to work in teams is a great asset and is much in demand. Therefore, university education must prepare graduates to work in teams. For example, Danaher et al use scenario-based teaching and evaluation with asynchronous discussion [4]. The result reveals that the students perform better in teamwork, although not across all the teams. Hence, it can be concluded that extracurricular activities in teams seem essential to prepare students for the 21st Century workforce [4].

Essig argues that the distribution of a course book tailored to the educational requirements and the students' background will be more beneficial to them. Students can access the book during the relevant semester and as it is free, it does not put an additional financial burden on the students. However, creating additional course materials is definitely a huge commitment in terms of time and other resources [5].

In-class demonstrations when teaching mathematics, physics, chemistry and engineering can improve the students' conceptual understanding. Fang applies a pre-test and post-test to analyse this method of teaching, and considering that students give positive comments on in-class instructor demonstrations it seems a good approach [6].

In view of the more demanding labour market, the wide spectrum of skills required by employers, and the studies highlighted above, the authors of this articles argue that learning through the combination of mathematics, algorithms programming and art in the form of batik motifs can be beneficial to engineering students in Indonesian universities, and will allow them to develop humanistic values. Batik motifs are specifically chosen because batik is one of the well-known forms of Indonesian art and an expression of local wisdom.

Batik is an Indonesian culture that is well known overseas. Every city in Indonesia has its own batik motifs. Currently, there is a whole variety of batiks available due to the influence of regional cultures and local wisdom. By using Turtle graphics, the millennial generation can learn about batik motif designs, and gain mathematical and programming skills in a combined approach.

TURTLE GRAPHICS IN THE PYTHON LANGUAGE

In order to draw curves or produce graphics, Python programming uses a feature called turtle graphics. Turtle is one of the libraries in Python to draw graphics. After the Turtle library is imported, graphic movements can be made forward, backward, right, left, etc. These movements will create a different shape when combined with another command, so that a lot of graphics or patterns can be generated.

Some simple Turtle commands [7] are as follows:

- forward (10) is to move the Turtle (arrow) forward by 10 pixels;
- backward (5) is to move the Turtle (arrow) back by 5 pixels;
- right (35) is to move the Turtle (arrow) clockwise at an angle of 35 degrees;
- left (55) is to move the Turtle (arrow) counter clockwise at an angle of 55 degrees;
- goto (x, y) is to move the Turtle (arrow) to position x, y;
- penup () is to disable the pen so that when the Turtle (arrow) moves, it does not create a graph;
- pendown () is to activate the pen so that when the Turtle (arrow) moves, it will create a graph [7].

METHODOLOGY

Students from the Faculty of Engineering at Maranatha Christian University, Bandung, Indonesia, were the subjects of this study. The study programme is focused on the attainment of mathematical and programming abilities, complemented with art elements. This is expected to be accomplished through making a batik-based pattern when programming. This study involved the following stages:

1) in the first meeting, students were asked to observe and recognise batik motifs, so that they could become familiar with the design of a batik motif;
2) students were provided with basic knowledge of Python programming and turtle algorithms;
3) they were given an assignment to make a particular batik motif (see Figure 1) using the turtle algorithm. They had to design the turtle graphics step by step, then implement them into the programming language and evaluate the result of the turtle graphics plot. If the result was not compatible with the given motif, they had to revise and re-program the turtle graphics, and check the result again. This had to be done repeatedly until the result was compatible with the intended batik motif;
4) After learning art for one year, students were given a questionnaire, to gauge their opinions and the development of their humanistic side.

Questionnaires were distributed after the training's completion. The trainer provided basic tutorials on Python programming and the turtle graphics algorithm. This was followed by assignments that had to be completed within a certain time limit. The task of making motifs starts from simple shapes and gradually progresses to more difficult motifs. Students were allowed to discuss any difficulties and issues within their groups and that way they could learn in teams, and gain teamwork skills.

The questionnaires were intended to gather data on students' way of thinking when making batik motifs, their efforts to connect the selected motifs with programs that had to be made in Python using the turtle graphics algorithm, their response to difficulty in training, the impact of the training on their social lives, their attempts to learn self-control. Students engaged in training based on logic, emotion, balance, proportion, shape and scale.

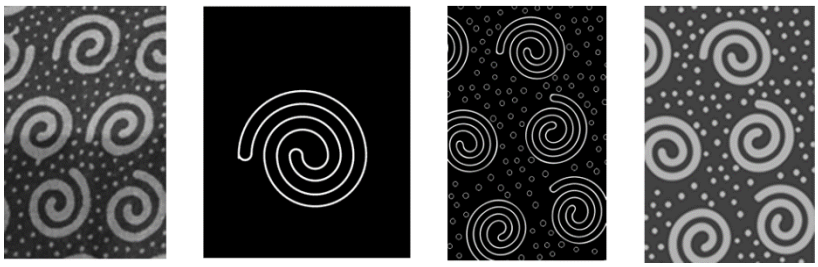
RESULTS AND DISCUSSION

Table 1 contains the respondents' data that relates to their gender, age, interest in learning art, place of birth (which province), their achievement index, their ability to solve easy motifs and the difficult ones. Once this data was collected, art education was provided to the Faculty of Engineering students who were interested in learning art. In this study, all 126 respondents were Indonesian students, including 74% male students and 26% female students; and 90% of the respondents were 17-22 years old. The study results indicate that 55% of the students were interested in learning art and participated in the turtle graphics training on making a batik motif.

Table 1: Data of respondents.

No	Data type		Number		Percentage	
			Male	Female	Male	Female
1	Gender		93	33	74 %	26%
2	Age	17 - 22 years old	84	30	67%	23%
		23 - 28 years old	8	1	6%	1%
		29 - 34 years old	0	1	0%	1%
		>35 years old	1	1	1%	1%
3	Interest in learning art	Yes	45	24	36	19
		No	48	9	38	7
4	Province of origin	Outside Java	10	3	8	2
		Java	82	31	65	25
5	Student achievement index		2.8-3.87	2.7-3.1	-	-
6	Ability to solve easy motifs		Good	Good		
7	Ability to solve difficult motifs		Good	None		

The results of making a batik motif can be seen below. Figure 1a is a picture of a spiral motif batik cloth given to the students; Figure 1b shows the result of the motif made with turtle graphics; Figure 1c is a repeated pattern of the batik motif; and Figure 1d shows the reconstruction of the motif, which has been coloured, made with turtle graphics. The students' creativity was being developed through a set of assignments of making a batik motif with a spiral shape using turtle graphics. The design criteria that students had to follow included the distance between the batik motifs, the degree of angle inclination and the equal size of the spiral.



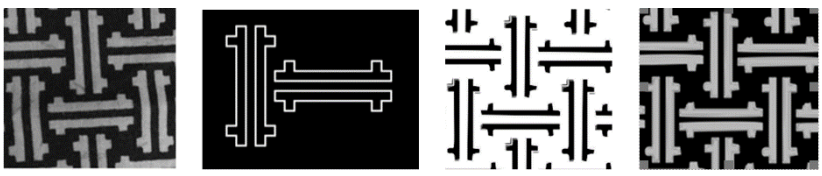
a) b) c) d)

Figure 1: Spiral motif: a) photograph of batik cloth; b) edge of the batik motif from the Python program; c) spiral motif after replication; and d) reconstruction of the spiral motif [8].

The spiral batik motif can be explained in the following way. Human life can be viewed as a spiral. When a person is born, there is a hair whorl on the head, in the shape of a very soft spiral, which is the idea behind the batik motif. This idea is visualised into a motif having a spiral shape and randomly composed. It is made in a repeated pattern to the left, to the right or rotated and positioned on the top and at the bottom. The background of the spiral shape shows a typical characteristic of batik, which are the dispersed dots. On the whole, this batik motif reminds one of a galaxy with stars dispersed on the sky at night. A spiral shape symbolises the galaxy shape that is surrounded by stars. This image is strengthened by the trace of batik resistors that show the white colour, so that the spiral batik motif with the white dots in the background becomes spectacular due to the black background that makes this motif even more impressive.

The shape of this spiral motif is circular and it becomes proportional when implemented to the batik motif made in the Python program. The scale used in Python is 1:1. Aesthetically, this batik motif demonstrates unity, and there is some harmony between the object and its background, whereas the black background and the white dots produce batik with contrasting colours.

The next example is the *banji* motif shown in Figure 2. In this assignment, students were required to arrange the composition, according to the accurate scaling and the suitable distance.



a) b) c) d)

Figure 2: Banji motif: a) photograph of batik cloth; b) edge of the batik motif from Python program; c) batik motif after replication; and d) reconstruction after colouring [9].

The banji motif shape shown in Figure 2 is arranged horizontally and interspersed vertically with the pattern repeated. This arrangement is repeated on the top intermittently using the opposite direction to the bottom part. This creates an interesting pattern. The play of shapes with the vertical and horizontal lines forms an interesting composition.

The banji motif has a black background. The right proportion is achieved by making all the objects exactly the same and repeated. Aesthetically the batik motif represents unity. The harmony is attained by the repeated objects with the same pattern from the left and right vertically and interspersed with the horizontal motif, so that they are symmetrical. The background and objects of this motif have contrasting colours.

The respondents who had completed their batik motif were asked to fill out the second questionnaire, the results of which are shown in Table 2. The objective of the questionnaire was to find out how the batik motif was designed, what impact it had on the students' humanistic development without their realising it, which was considered important.

Table 2: Questionnaire results.

Question	Summary of answers	Analysis
What comes to your mind when given a batik motif?	A picture of unique and traditional motifs, drawing, simple to complicated pattern, preserving batik motifs.	According to students, a batik motif is unique and can vary from simple to complicated drawings; they are able to assess the level of difficulty of the motif they have to create.
How do you interpret a motif?	Searching for literature about batik motifs identical to flowers leaves. The steps involve making a simple motif first, then tracing the motif.	Students are trained to look for the meaning of the batik motif, then analyse it and think how to begin the creation of batik motifs, and how to proceed with the creation.
Is turtle graphics easy to understand?	Yes, it is, but hard to make; it needs practice to create batik motifs; easy when using a program.	Students are asked to get interested in learning art, which is easier when using their programming skills.
How did you make a batik pattern? (what steps did you follow?)	Drawing the motif and measuring, then making the Phyton program with the turtle graphics algorithm. The motif is seen as a big pattern first, then the details are added.	Students are trained to identify the main part and then specify the details to be added. They are trained to be able to use the Python program to create a batik pattern.
What difficulties did you encounter?	Determining the right composition, calculating, measuring, imagining the motif with a lot of angles, motif with a lot of details, controlling emotion.	Students are trained to be able to determine the accurate composition, size, shape, big and small motifs. Students' patience is trained in finishing the batik motif, especially when the motif is difficult.
How is your social life?	Good, quite good, can have a social life without any problems, can interact with friends.	Students are trained to be able to interact with their friends and those around them.
How do you control your emotion?	Good, very good, even in a situation full of pressures, a bit too much.	Students are trained to control their emotion; they can still finish it in a difficult situation.
What is your logical ability?	Good, moderate, logical ability can depended on different factors, can do activities requiring complex and critical solutions.	Students are trained to solve a problem by starting with small steps then proceed to bigger ones until the problem is solved.
What is your programming ability?	Good, moderate, the basic program is mastered, the advanced program needs further study.	Students are trained to increase their ability to finish the batik motif by making a program and selecting the right commands when solving problems.
What shapes have become your favourite or what shapes can you make? Name 3 motifs.	Circles, flowers, abstract, *parang kusumo, parang rusak, parang tuding, mega mendung, kawung, kopi pecah, sata ganda wangi*.	Students are trained to be able to select the motif according to their taste, and regard batik as a work of art based on various shapes.
What shapes do you not like or what shapes you cannot make? Name 3 motifs.	Triangles, squares, uninteresting shapes, *parang klitik, parang pamor, parang lawasan*, animals, human beings, sceneries, *mangrove rungkut, kalangbret, bolleches*, difficult motif with details.	Students are trained to differentiate batik motifs, which have interesting shapes and aesthetic values.
How do you determine the proportion or comparison when making a motif?	Using mathematical formulas, measuring, calculating angles and lengths, can be a trial and error, doing the simple one first, using variables, so that it can be changed to accommodate the window size that is too big or small.	Students are trained to determine the proportion or comparison of an object, using the knowledge learned to solve problems.

How do you arrange the scale in the batik motif?	Calculating and making the motif, so that it can fit the window of 800 x 500 pixels.	Students are trained to put a motif or solve a problem within the space provided by calculating all the aspects.

Based on the results of this study, the batik motifs produced by male and female students show certain similarities. However, the complexity of motives demonstrated in male students' works appears higher than that of female students, and the completion time of male students' works was also shorter. Nevertheless, both the male and female students completed the motif creation assignments with good results.

The achievement index of students who completed the batik motif assignment is 2.7 out of the scale of 4. Based on two years of observation, students who can complete this batik motif assignment succeed in reaching the final semester of learning, as the perseverance and willingness to learn instilled during the assignment is beneficial in solving the problems they encounter.

CONCLUSIONS

The students in the Engineering Faculty at Maranatha Christian University have experienced a significant change in their abilities and attitude, which can be seen from the findings of this study; namely:

1) increased patience, persistence, willingness, geometrical perception and abstraction ability;
2) ability to transform a batik pattern implemented in the program, so that it forms mathematical graphics or turtle graphics;
3) improved co-operation skills and readiness to help one another in the group.

Both male and female students demonstrated equal ability to engage in the learning process. The batik motif they made with the program is similar to the original motif. This study shows that the students' ability in creating the program will help them to observe shapes and sizes; develop their abstraction ability, and programming algorithm skills. This training can also be very beneficial to their social life.

The questionnaire method used in this study involved 126 engineering students. All of them were Indonesian, and 74% were male and 26% were female students. Ninety percent of the respondents were 17-22 years old. The findings indicate that 55% of the students were interested in learning art, and participated in the turtle graphics training on making a batik motif. The conclusions are:

1) the creative functioning of the brain can be improved through learning with batik motifs;
2) participation in batik motif training improves social skills and interaction outside class;
3) the ability to create a batik motif can be assessed by the shape, proportion and the scale of the created motif.

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