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Students' competence Development on Learning Fractal Geometry by Experiments Using ICT Tool

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Abstract—The new curriculum of high education based on competence of graduates. The competencies that students should develop are comprehending the knowledge and use it to solve the problems by explorative and experiments activities and using appropriate ICT tools. One of the subjects of mathematics that students learn is Fractal Geometry. Geometry is one of the oldest mathematics sciences that never stop to be studied and be developed. The newest geometry that brings us some new perspective is Fractal Geometry. Fractal Geometry based on study about how look like a continuous function that is not differentiable everywhere and this subject brings us to new concepts of dimension that can be a positive rational number. When we study about fractal geometry, one of importances things is how can we develop some fractal objects. One method that can be used to create fractal objects are Lindenmayer system. In order to develop competencies of students, the lecture emphasised the experiments task and used ICT tools to help the students to create some fractal objects. This paper will present how experiment activities using ICT tool helped students to create fractal objects by Lindenmayer system.

Keywords: *students'competence, Fractal Geometry, learning by experiments, ICT Tool.*

I. INTRODUCTION

The new curriculum of high education is based on the competence of graduates. The competences that students should develop are comprehending the knowledge and use it to solve the problems by explorative and experiments activities and using appropriate ICT tools. Experiments in mathematics here is an approach using an ICT tool to investigate fractal objects and identify properties and its patterns. With these experiments, the students generate and confirm or confront their conjectures so that they can understand more about the subject they learn than just a theory and can develop some strategies to solve the problems. By using ICT tools, they can discover some new patterns and make a relation and construct some conjectures and testing their conjecture easily. The ICT tools or computer program that are used in this research is open accsess and students are asked to choose the appropriate tool.

The term "fractal" was first used by French-America mathematician, Benoît Mandelbrot in 1975. Mandelbrot based it on the Latin, frāctus meaning "broken" or "fractured", and used it to extend the concept of theoretical fractional dimensions to geometric patterns in nature. A fractal is a mathematical set that has a fractal dimension that usually exceeds its topological dimension and may fall between the integers. Fractals are typically self-similar patterns, where self-similar means they are "the same from near as from far" and exactly the same at every scale.

One method that can be used to create fractal objects is Lindenmayer system or is called by L-systems. Lindenmayer systems were introduced by Aristid Lindenmayer as mathematical formalism for modeling multi cellular organisms that form linear or branching filaments. The basic idea of this system is forming complex objects by successively replacing parts of a simple initial object using a set rewriting rules or productions, usually is done recursively. L-systems are parallel rewriting systems operating on strings of symbols. Lindenmayer system is formed by initial state or axiom, a set of symbols contain production rules. Many fractals can also be thought of as sequences of line segments, depends on the lengths of the line segments and the angles between the line segments.

Example of a Lindenmayer system:
Axiom : -F
Rule : F=F+F-F-F+F (means that we replace F with F+F-F-F+F)
Angle : 90 °
The product of this system are:
n=0, -F
n=1, -F+F-F-F+F
n=2, - F+F-F-F+F + F+F-F-F+F - F+F-F-F+F - F+F-F-F+F + F+F-F-F+F
and so on.

To produce fractal objects, the string generated by Lindenmayer system must contain the necessary information about geometry figure. One interpretation of a string is turtle graphic which translate symbol or string to geometric forms. Geometric Interpretation of the symbols or string are:
F : means move forward one step.
+ : turn left by angle θ
- : turn right by angle θ (is equal 90° if is not determined)
By geometric interpretation above, for n=1 , -F+F-F-F+F we have :

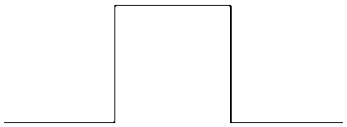


FIGURE 1. FIGURE FOR N=1

And for n=2, - F+F-F-F+F + F+F-F-F+F - F+F-F-F+F - F+F-F-F+F + F+F-F-F+F , here we replace every representation of F by the form of n=1, and the form is below:

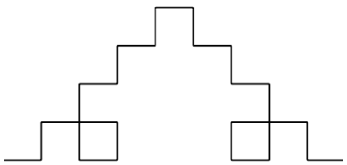


FIGURE 2. FIGURE FOR N=2

If the process continue recursively, for n=5, we have this form:

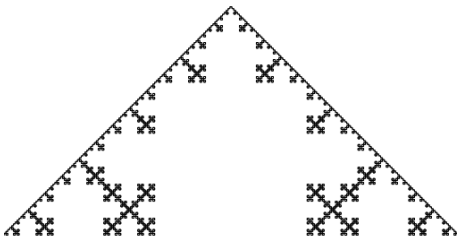


FIGURE 3. FIGURE FOR N=5

II. LEARNING FRACTAL BY EXPERIMENT ACTIVITIES USING ICT TOOL

A. Aim of the research

The aim of this research were to describe how the experiments activities using ICT tool helped the students to develop their competencies to constructs fractal objects and found the relations between the rule of the Lindenmayer system, the angle and its geometric interpretations.

The aims of learning geometry fractal by Lindenmayer systems by experiments are:
(i). The students understand about this system and know how to use this system to create an fractal object.
(ii). The students develop some strategies by experiments when construct a system for some object that are given.
(iii). The students realize the relations between length of line segment, the angle and the object.

B. Subject and method

The subjects of this research were Universitas Negeri Surabaya undergraduate students of fractal geometry class, consisting of 20 students.
To know about the role of the experiments activities using ICT tool in Fractal learning, at first the students were asked to do the tasks without experiments using ICT tools, after several time they worked for the same tasks with experiments using ICT tool that they chose.
The works with and without experiments activities were analyzed and compared.

C. The tasks

The tasks are given to students to construct fractal object by Lindenmayer system were four tasks.
TASK 1
Give the geometric interpretation for n=1 to n=3 of the following Lindenmayer system.
Axiom : F
Rule : F=F+F- - F+F
Angle : 60°.

TASK 2
Given the following image of a phytagorean tree and find the Lindenmayer system for this image.

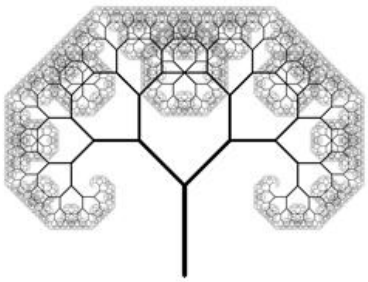


FIGURE 4. FIGURE OF PHYTAGOREAN TREE

TASK 3
Contruct a Lindenmayer system of marigolds leaves (in bahasa: daun kenikir) in which the image is given the following. Describe your strategies to form letter "S" for the stem leaf.

FIGURE 5. FIGURE OF MARIGOLDS LEAVES

TASK 4
Find an object in your neighborhood, take a photo of this object and construct the Lindenmayer system of this object and give the geometry interpretations of your system.

D. Results

In this section, we describe the works of students with and without experiments using ICT tool.
TASK 1.
There was no different results before and after experiments activities. Almost all students gave the same image, before the experiments they did the interpretation of the given system using ruler and protractor to measure the angle, and after experiments using ICT tool they found the similar shape, looked like the following image:

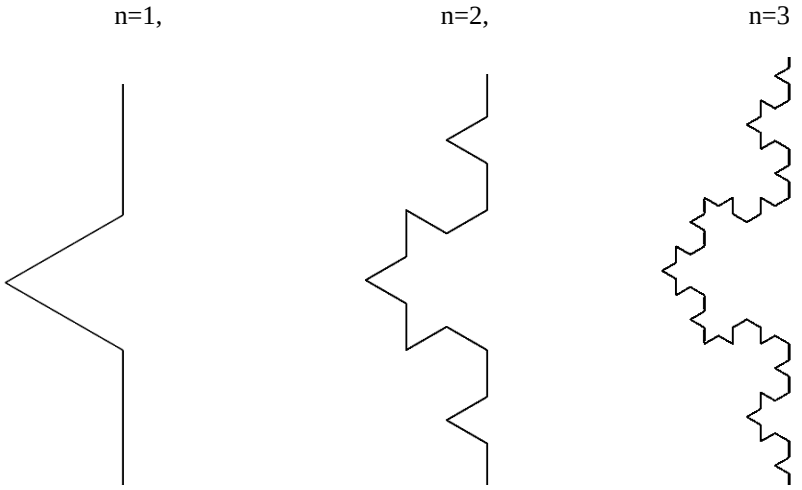


FIGURE 6. GEOMETRIC INTERPRETATION OF THE SYSTEM

TASK 2
Using ruler and protractor, the students measured the lenght and the angle between line segment and the create the system of this Phytagorean tree. The strategies that they used are focus on the stem of the tree and characterized the repeated pattern.
The system that they found without experment did not respect to accuracy of line segment ratio. Here, the Lindenmayer system and geometric interpretation of almost all students,
Axiom : XF
Rule : F=F[+F][-F]
Angle : 45°.
The geometric interpresentation for n=1, 2, 3 and 5.

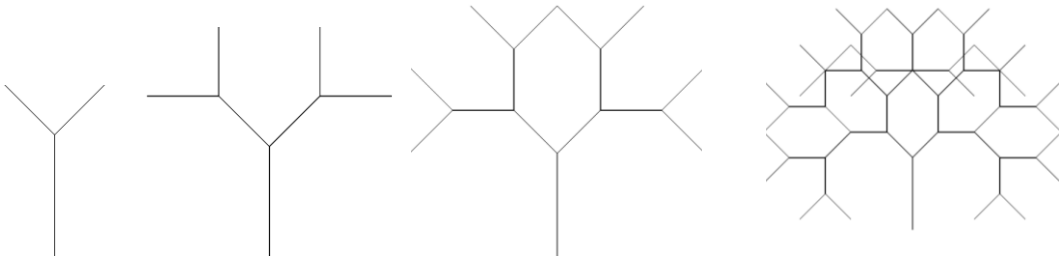


FIGURE 7. PHYTAGOREAN TREE WITHOUT EXPERIMENT

When they used ICT tool to experiment with, they could change the system and saw the changement they made about the ratio of the line segment and rechanged again and again to get the better geometric image.

TASK 3

Before experiments activities, 75% of students said that it is impossible to construct Lindenmayer system for the stem leave with the form "S" shape using line and the angle., and the rest of them said they did not know how to make a "S" shape. The system were created did not product "S" shape for the stem leaves.

The Lindenmayer system :

Axiom : X

Rules : X=F[+X][-X]FX;
F=FF

Sudut : 27^o and the following interpretation for n=1 to 3 respectively.

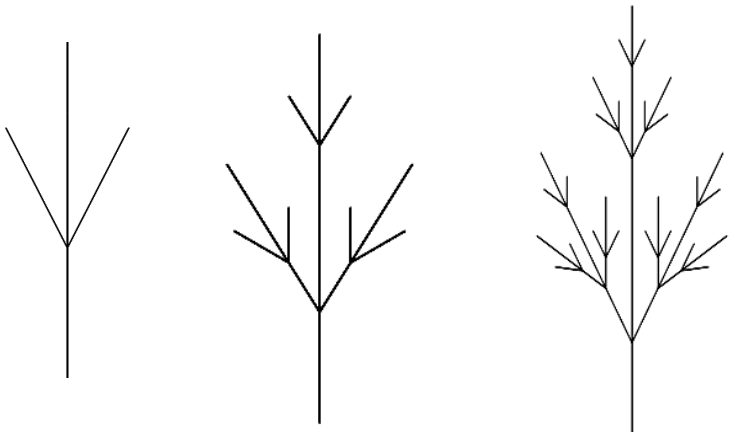


FIGURE 8. GEOMETRIC INTERPRETATION WITHOUT EXPERIMENT

After experiments activities using ICT Tool,

More than 75% of students realized that is possible create "S" form by using line and the angle and after some trial and error they could construct Lindenmayer system for the leave of marigolds. They used the strategies by change the angle small enough to have smooth curve for the stem leaf.

Here the several results of this task, the system and the geometric representations.

(a). Aksioma:

F-F-F-F-F-F-F-F-F-F-[---FFFFFA][F+F+F+F+F+F+F+F+F+FF-F-F-FA][++++++++++FFFFFA]

Rules: F=FF

A=[-----FFFFFFA][FFFFFFFFFFA][+++++FFFFFFA]

Angle = 7^0

The strategies they used: form a shape of "S" using small angle in axiom for the stem leaf and created the rules for the leaves.

The interpretation using "Inkscape" the produced this image:

FIGURE 9. INTERPRETATION USING INKSCAPE

(b). Axiom :

F-F-F-F-F-F-F-F-F-F[F-F-F-F--F--A][F+F+F+F+F+F+F+F+F+FF--F--F-FA][++++F++F++F++F++FA]

Angle : 7°

Initial Angle : 31°
Rules : A=[-----FFFFFFA][FFFFFFFFFFFFA][+++++FFFFFFA]
F=FF
By using fractal grower, they produced this following image;

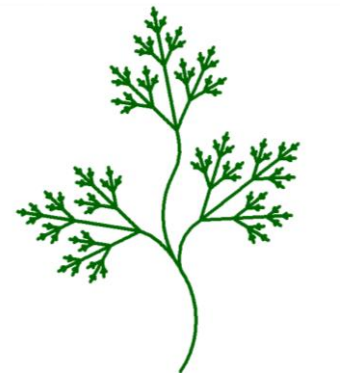


FIGURE 10. INTERPRETATION USING FRACTAL GROWER

TASK 4.
After the students made the constuction for "S" shape, they could create different shape more fluently than before, it is shown from their constructions for this task, when they chose the object freely that they could find in their neighbourhood and the ICT that they used.
Here, some of the works of students,
(a). "Samber gledhek" flower is created using " Fractal Grower".

FIGURE 11. SAMBER GLEDHEK FLOWER

Aksioma : ![G][+++F][---F]
Aturan : F=![G][++F][--F]
G=HG
Sudut : 13°

These are the fractal grower production for this system with n=1, 2 and 8 recursively

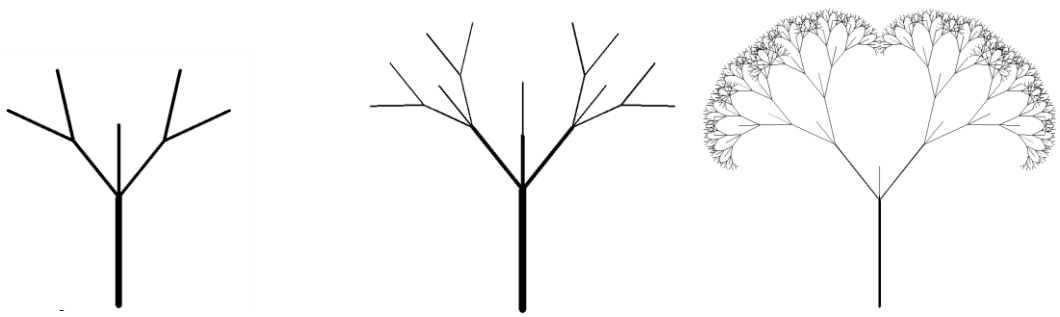
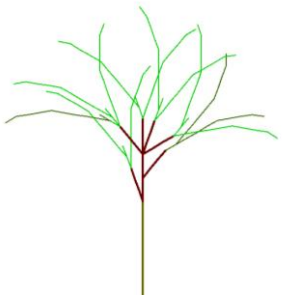


FIGURE 12. GEOMETRY OF SAMBER GLEDHEK FLOWER

(b). Palm tree created by fractal grower

FIGURE 13. PALM TREE

Axiom : !!!![-FFFA]FF[++FFFC]FF[--FFFB][+FFFA][--FFFA][+++FFFD]FFFD
Rules : A=AA[+FFFFF+FFF+F]F[-FFFFF-FFF-F]FA
B=B[+FFFFF+FFF+F]-FC[-FFFFF-FFF-F]FB
C=C[+FFFFF+FFF+F]+F[-FFFFF-FFF-F]FC
D=A[+FFFFF+FFF+F]-F[-FFFFF-FFF-F]FC--A
Angle : 20
The interpretaion of the system using fractal grower for n=1,2 and 4 recursively



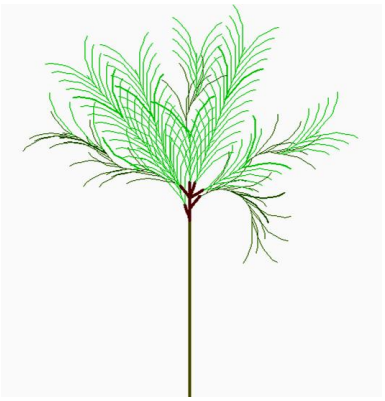


FIGURE 14. GEOMETRY OF PALM TREE

(c). Radial tire of a car

FIGURE 15. FIGURE OF RADIAL TIRE

The Lindenmayer system of this tire is:
Axiom : +F+F+F+F+F+F+F+F+F+F+F+F
Rules : F=A[+A][- - - - -A][A++AA- -A++F]
Angle : 30
The interpretaion of the system using inkscape for n=1,2 and 4 recursively.

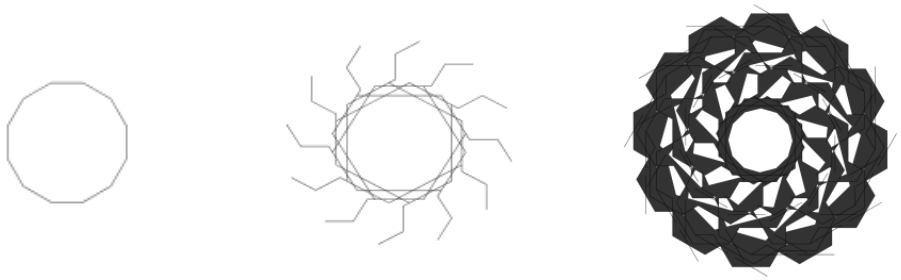


FIGURE 16. GEOMETRIC OF TIRE

III. CONCLUSIONS

From the analized data of the works of students before and after experiments activities, we have:

1. Using the experiments activities with ICT tool, the students realized that a shape "S" can be created using lines with the angle small enough so that the curve is smooth. In other words, the students made a relation between the shape and the angle.
2. The use of ICT tool and experiment activities, helped the students to make a guess about their system for an image and check it and change the system to make a better geometric representation of the system.
3. With using ICT tool, the student could create systems for variuos fractal objects that was difficult to realize without ICT tool.

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