A Fractal Geometry Logo-based microworld for Graphic Design graduate students

Enís Castellanos

Universidad Iberoamericana-Puebla

Km 3.5 Carr. Fed. Puebla-Atlixco
72430 Puebla,Pue., MEXICO

eniscast@prodigy.net.mx

Ana Isabel Sacristán

Cinvestav-DME

Av. IPN 2508, Zacatenco
07360 México D.F., MEXICO

asacrist@cinvestav.mx

Abstract

We present a proposal of a course designed to introduce Fractal Geometry, in a meaningful way, to graduate students of Graphic Design, using Logo-based activities; we also present some results of the study we carried out to evaluate this proposal. The implementation of Fractals to Graphic Design responds to the need to handle new tools for the graphic designer that will allow him create new and more innovative design products. The challenge we faced was to produce a pedagogic proposal that would facilitate meaningful learning, so that students would be able to apply the new knowledge in their work.

Keywords

Fractal Geometry, Graphic Design, Logo, Curriculum Design, Collaborative Learning, Meaningful Apprenticeship

1. Introduction

In this paper we present how we have been using Logo as a tool for introducing Fractal Geometry to students of Graphic Design, following up on the paper we presented at Eurologo 2003 (Castellanos & Sacristán, 2003). The rationale for introducing Fractal Geometry into Graphic Design studies using Logo, was presented extensively in that paper.

Here, we delve deeper into how we designed a graduate-level university course and Logo microworld activities to incorporate Fractal Geometry into Graphic Design studies in a meaningful way (using constructivist principles and emphasizing collaborative work to encourage the exploration and learning of the mathematical concepts); and present the research we carried out to evaluate its implementation. We present one of the activities to illustrate the nature of the microworld and give some examples of the students work that summarize the application of their fractal knowledge on a graphic design product. Finally we give some pedagogical recommendations.

2. From the pilot to the main study: The evolution of the design of the course

In Castellanos & Sacristán (2003) we described in depth the results of a first pilot study where we designed a graduate-level semester-long course to introduce Fractal Geometry to Graphic Design students. This course was based on several sets of activities; mainly paper-and-pencil ones but that also included a small module of Logo-based ones. We explain there, how the potential of Logo was revealed. For the pilot study, we had taken into consideration the type of students we were dealing with (graphic design students), and had assumed that the students would prefer paper-and-pencil or graphic design software activities to intensive Logo programming, since the incursion of descriptive geometry, due to its mathematical content, would already cause tension without also having to deal extensively with the programming language. We were wrong. The result was surprising: the students were upset when the Logo activities ended, so they tried to explain the ways in which they could solve the paper-and-pencil activities with Logo and some of them even tried to do them.

Analyzing their attitude, it seemed to us that the students engagement in attempting to solve the problem with Logo led them to find their very own personal solution: they discovered their very own way of thinking for problem-solving. This again proves that Logo is a perfect tool for “thinking”. When a student learns to program, his learning process is transformed: It becomes more active and self conducted. The knowledge gains an identifiable personal purpose.

Another appeal of Logo for the students was its visual component and the turtle geometry, which they felt was attractive and fun: because the response of the turtle is immediate, they found it relatively easy to learn to move the turtle and to translate the task into Logo language.

2.1. Towards a new proposal: a Logo-based microworld

Taking into account the positive influence that the Logo activities had in the pilot study, and also realising that our first attempt did not follow enough of a constructionist approach, we restructured the design of our proposal, so that the entire course was supported by Logo activities and was closer to the Logo philosophy. In the new course proposal, we incorporated Logo activities all along the semester as support to each topic related to fractal mathematics.

Furthermore, it was clear that we needed to reconsider the entire environment in which students’ learning of fractal geometry was to take place. We thus investigated the concept of microworlds, first as incubators for powerful ideas (Papert, 1980), but also in the broader sense defined by Hoyles & Noss (1987) where: “the way a pupil interacts with Logo, even when structured so as to encapsulate ‘neat phenomena’, is crucially influenced by the didactical situation in which the interaction takes place (ibid, p.587).”

2.2. Some theoretical considerations

Our challenge was to describe the geometry of fractals through Logo while connecting this new fractal knowledge to graphic design areas. We wanted to do it by bringing “meaningful apprenticeship”. At the beginning of Logo’s history, Papert proposed the concept of microworld as a prototype of an apprenticeship environment in which Logo had a central role. In his book *Mindstorms* (1980, p.120) he describes a microworld as a knowledge incubator where the first thing to do is to relate the new material to be learned with knowledge that the student already has. Then the new knowledge becomes part of the student’s knowledge when he develops something new with it, plays with it, builds something with it.

According to Hoyles & Noss (1992) the constructionist essence of Papert’s paradigm relays in the dialectic between the design of apprenticeship environments and the effort to describe what happens inside this environment that allows students to learn. It seems that an expressive channel has been developed as a characteristic of the constructionist apprenticeship environments. The expressiveness refers to the possibility of expressing ideas (mental objects) in a concrete way (visible objects). Hoyles & Noss (1987, p. 591) use the term “self expressive” to emphasize the way in which a computer medium can become a place where the mathematical actions can be developed and reflected upon. They consider that a microworld involves four components that interact among themselves: the Pedagogic component, the Technical component, the Contextual component and the Student component.

Diaz-Barriga & Hernandez (1998) establish two conditions for making the apprenticeship meaningful. First, they consider that it is necessary for the information to relate to the student's previous knowledge in a non-arbitrary and substantial way –what we consider the *cognitive aspect* of the student component of a microworld. Secondly they argue that success depends on a) the disposition –understood as the motivation and the attitudes towards learning–, b) the nature of the materials and c) the contents for apprenticeship; these we consider relate to the *affective aspect* of the student component. They add that the way the content will be transmitted should not be established by the background of the teacher but by the interest of the students. In our case, the path that a teacher (with a strong mathematical background) will follow for explaining the contents may be hard for students to follow; therefore, the teacher should always keep in mind that the student background is that of a graphic designer. This is what Diaz-Barriga & Hernandez refer to when they use the term "non-arbitrary". They also explain that when the content is non-arbitrary, synonyms can be found for the examples and around the same concept. This is called "substantial relationability". Both the non-arbitrariness and the substantial relationability relate to the pedagogic component, although the latter also refers to the contextual component because in some cases, the same knowledge can be used in different tasks. The non-arbitrariness is a strong concept in Logo programming: there is no single way to solve a task; Logo allows students to make their own decisions and to study their path for different or better solutions.

If this apprenticeship becomes meaningful, the graphic design student will relate the new fractal concepts to his design work.

3. A Logo-based fractal mathematics microworld for graphic design

Taking the above principles into account, we restructured the whole design of the course, creating a "fractal mathematics microworld for graphic design" that placed emphasis on the entire didactical situation - the four components of a microworld as defined by Hoyles & Noss (1987). As explained above, the need of creating a microworld that took into account the components became evident after the pilot study: In that phase, there was "something" missing, "something" that could articulate all the elements that were interacting during each session: a microworld that would take into account all the components.

First, the activities (the pedagogic component) were re-designed in light of the constructivist theory, taking into account the population (the student component) they were intended for, and became constructionist exercises, as will be described further below. Second, an adequate role of the teacher, as guide and mediator, was indispensable. Third, we promoted collaborative work by suggesting that pairs of students or small groups work together (the contextual component). Working in this way can trigger certain apprenticeship mechanisms (although we are aware that there is never any guarantee that this will happen). Following Vygotsky's (1978) ideas, we believe that students are capable of moving to higher intellectual levels when they are asked to work in collaborative situations. The diversity in terms of knowledge and experience contributes positively to the apprenticeship process. They feel more responsible of their own apprenticeship and the apprenticeship of their partners.

One way in which we promoted this, was by limiting the resources given in order to create positive interdependence among the students, forcing them to work together to finish the task.

3.1. The design of the activities.

In contrast with the pilot study, from the beginning, the course included computer-based activities. Using Microworlds Logo, we designed pre-built interactive microworld pages, that can be loaded at the beginning of each session, but that also allow students to create their own projects. These interactive pages are thematic and are composed of three sections: the informative section, the exploration section and the exercise section. The informative section gives content support: it provides pre-loaded summaries and main ideas of the theoretical information related to each topic of fractal geometry, built into the computer environment so that it is interactively available to students (students can return to the informative section at any time during the exploration phase if they need to). The exploration section has some pre-programmed examples that students can explore and play with (e.g. by changing some of the variables) and where they can attempt to predict the effects of their changes on the resulting figures. Finally, the exercise section provides some problems to be solved. It may contain "hints" to help the student complete the tasks, but he wont be allowed to return neither to the informative nor the exercise section. These problems include the free construction of some pre-determined figures and those of students' choosing. For example, for the topic of recursion and iteration, we have pre-built three fractal figures: Trees, Sierpinski's Triangle and Koch's Snowflake. Students can explore variations of the number of substitutions within each figure, and also build their own procedures.

In our course proposal, we had twelve interactive sets of activities. Below, we present an example of one of them.

3.2. Example of an activity: The Symmetries Activity

The activity is divided into two sections: the informative section –where the different types of symmetry are defined– and the guided exercises section. The student can navigate from one type of symmetry to another as he wishes in the informative section, where he can also solve very simple Logo exercises that will help him understand the structure of each kind of symmetry. Once he gets into the guided exercises, he is not allowed to return to the information section. In these exercises, he must formally describe, through Logo programming, the behavior of each of the figures presented for the different types of symmetry.

In addition to the interactive computer page, there is an accompanying paper-and-pencil worksheet. Each student is given a worksheet but encouraged to work in pairs.

<u>The interactive pages of the Symmetry activity</u> (Figure 1)

General objectives: The transition from the known concepts of symmetry (horizontal, vertical and radial symmetries) to the introduction of a new concept: self-similarity. To introduce, in an intuitive manner, the concept of recursion and recursive programming.

Specific objectives: Analysis of the turns of the turtle according to each type of symmetry. Practice of the use of primitives. Introduction to the concept of recursion. Use of a stop condition in recursive procedures.

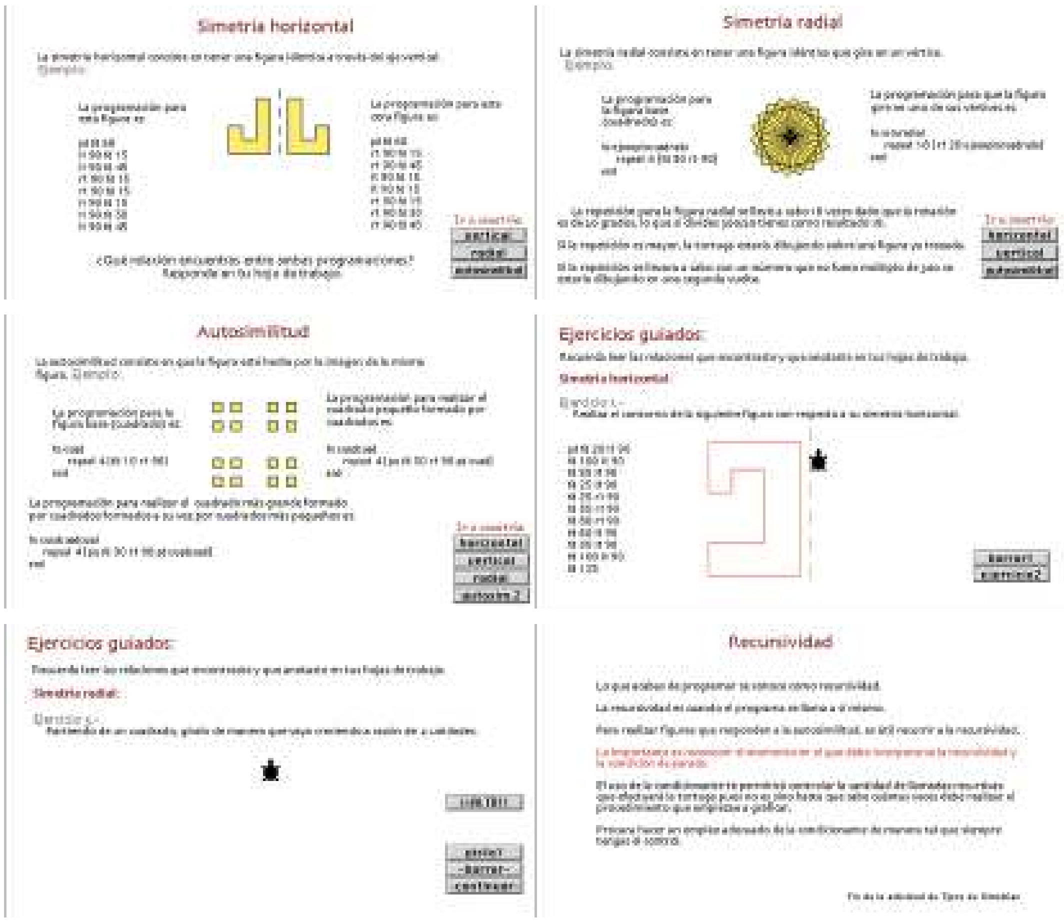

Figure 1. Some screenshots of the interactive pages of the Symmetry activity (in Spanish)

Description: First some examples of the horizontal, vertical, radial and self-similarity symmetries are shown, and students have to program each case noticing what changed from one to the other. Then they have to solve some problems where they need to apply recursion. Although they haven't been taught in-depth about such concept, they are asked to try to use recursion (with a stopping call) on the radial symmetry exercise. There is a hint button that offers a little more information about recursion, but doesn't include the solution. There is also a Stop button, to stop infinite loops they might accidentally create in their programming attempts. The hint button offers three clues, but each clue cannot be accessed without reading the previous one.

The discussion of the programming solutions to each task creates positive-interdependence among the students.

<u>The Symmetry activity worksheet </u>(Figure 2)

Description: The aim of worksheet is to encourage students to analyze the Logo procedures that produce figures through horizontal and vertical symmetries, and find the relationship between them.

Strategy: It's up to students if they want to work by themselves or in pairs or small groups, but they will be encouraged to discuss the possible solutions among themselves.

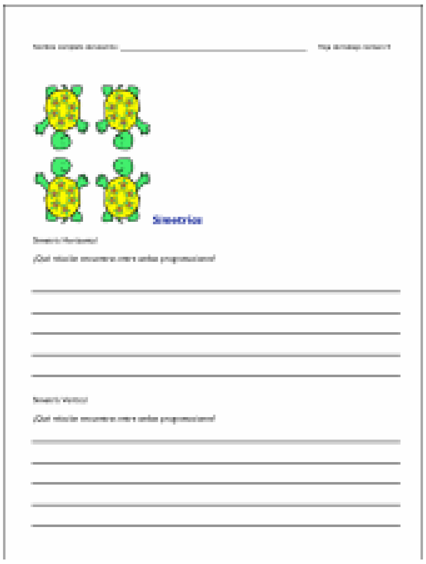

Figure 2. Symmetry Activity Worksheet

4. Description of the study

In order to evaluate the design of our course and activities, we carried out a study during which we tried it out over two academic semesters, from August 2003 to July 2004. In this study, we observed the individual and group processes that took place during the course. The course was registered as one of the required "project" courses that are part of the graduate-level Diploma degree on Digital Design at a Mexican university, so students received credit towards their degree. The course was taught and conducted by the researcher (the first author of this paper) as is described further below.

4.1. Characteristics of the participants

We had five graduate students enrolled in the Diploma degree on Digital Design who voluntarily agreed to participate in the study. Table 1 describes the characteristics of these participants at the beginning of the study:

Table 1. Characteristics of the participants

Name	Gender	Age	College degree	Graduation date	Master degree	Income	knowledge on fractals	knowledge on Logo
Josie	male	23	Graphic Design	2002	no	free lance	no	no
Javier	male	25	Graphic Design	2002	no	free lance	no	no
Gaby	female	31	Graphic Design	1994	no	free lance	no	no
Rocco	female	33	Architecture	1992	not finished	free lance	no	no
Susana	female	45	Graphic Design	2003	No	free lance	no	no

4.2. Data-gathering techniques

The data-gathering techniques of the study were:

- Field-notes from direct classroom observations by the teacher-researcher.
- Digital videotapes of all the sessions.
- Students' procedures and dribble files (the interactive activities are programmed to save the procedures and what is typed in the command center, each time the student changes the page).
- Students' written answers on the worksheets and in questionnaires.

- Students' narrations of the design-process of their final work.
- Informal interviews by the teacher-researcher with each participant.

4.3. The role of the teacher-researcher

The teacher-researcher's role was that of a guide and mediator and established a continuous negotiation. She was careful not to solve the problems for the students but rather to let the students find the solutions on their own. If a student had difficulties or doubts, the teacher-researcher helped him/her to analyze the question by discerning the elements involved, and perhaps helped him/her construct the solution by analyzing the results of his/her trials and errors.

We observed that there were three moments during the teaching practice: the *traditional moment* where the teacher gave the new information to the students, the *transition moment* where the teacher left behind his protagonist role and became another participant of the group while overlooking the educational environment, and the *teacher-researcher moment* where the teacher observed everything that was taking place in the classroom: the students' behavior, the teacher's performance, the materials that were being used, etc.

4.4. The learning environment during the interactive activities

Students learned the basis of Logo while the first theoretical lesson of the course was being taught. On the fifth session, the interactive activities began. The interactive activities created a brainstorming environment in which the students discussed amongst themselves their progress or placed themselves so that they could peek on others' computers. Each student had the opportunity to work at his/her own rhythm. Because during the exercise sessions, students no longer had access to the information section, it encouraged discussion among the students as they seeked help from their peers who still had access to section.

It is interesting that although the students were encouraged to work collaboratively if they wanted, and some work was in fact done in pairs or small groups, and students walked among the computers, they always returned to their own place to try to solve the task by themselves. There did, however, discuss their findings with their peers.

5. Application of the new fractal knowledge on a graphic design product

One of the ways in which we evaluated the efficacy of the course was by asking students to produce a graphic design project that used Fractal geometry creatively (and not just as a decorative item), applying the new knowledge we hoped they had gained. For this final project, students were asked to present a written work where they described their intention and their design process with their sketches.

5.1. Theoretical framework for evaluating the final project

For evaluating the level of application of the new knowledge, we considered Frauenstein's (1993) description of the three types of knowledge in mental models. The first one is the *declarative knowledge*, where the student only receives the new information. It can also be thought as the Piagetian *intra*-objective or *intra*-figural moment (Piaget & Garcia, 1982). In this process the student interprets reality and builds his own version of it using his previous knowledge and experiences, analyzing the objects. The second one is the *procedure knowledge*, where, through his personal experience the students learns *how* to use the new knowledge. This corresponds to the Piagetian *inter*-objective or *inter*-figural moment that studies the relations and transformations on the objects. Finally, we have the *conditional knowledge*, which is to know *when* to use the new knowledge. This relates to the Piagetian *trans*-objective or trans-figural moment. It is the moment when mental structures are built that allow going further than the simple knowledge of the object itself, and the learner is aware of the repercussions of such object in the environment.

5.2. Some results from the final projects

We used the above theory to evaluate and categorize the type knowledge that was built into the final projects (declarative, procedural and conditional) as well as the corresponding Piagetian moments. We summarize our analysis in Table 2 and present examples of some of the students' work.

Table 2. Evaluation of the final projects

Name	Type of project	Transference level	Type of knowledge	Moment	Fractal concept used as …
Gaby	Redesigning a game	medium and high	procedure and conditional	intrafigural and transfigural	Structure and behavior
Javier	Web-page design	medium	procedure	intrafigural	structure
Josue	Typographic design	medium	procedure	intrafigural	structure
Rocio	Park design	medium	procedure	intrafigural	structure
Susana	Coffee logotype	none	none	none	no fractal concept was used

<u>Gaby - Redesigning a board game</u> (Figures 3 & 4)

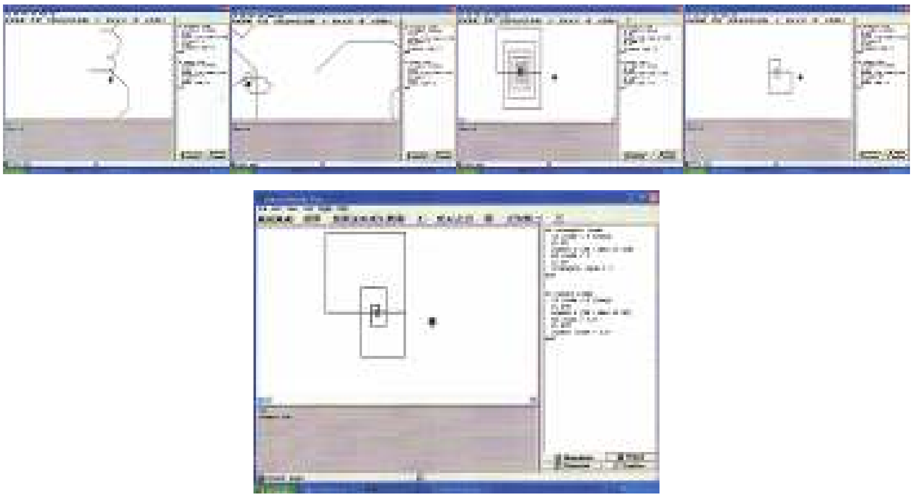

Figure 3. Gaby's Logo sketcher of her idea.

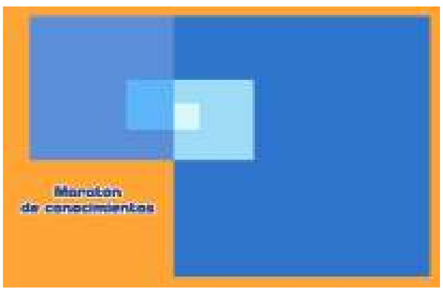

Figure 4. Gaby's final design of the board of the game.

```
to cuadro :lado
      if :lado < 5 [stop]
      rt 270
      repeat 4 [fd :lado rt 90]
      fd :lado / 1.8
      rt 270
      cuadro :lado / 1.8
end
```

Gaby designed a board-game about the city of Puebla (Mexico). Gaby used Logo for working-out and sketching her idea. She used a fractal structure for the game area.

Javier - Designing a web page (Figures 5 & 6)

Javier chose to design a web-page. He used Logo to try out and work on his ideas until he found a satisfactory design.

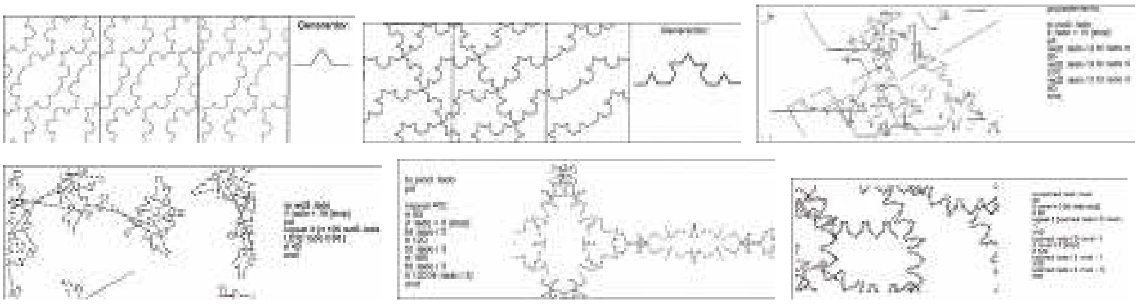

Figure 5. Javier's Logo sketches for working-out his idea.

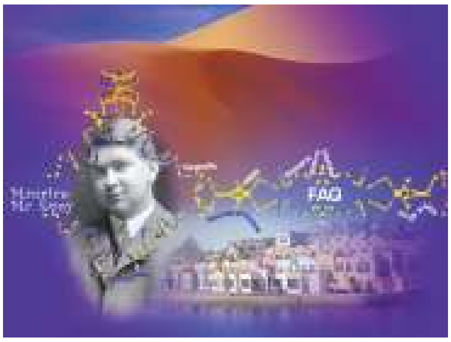

Figure 6. Javier's final form for the structure of his web page.

Rocio - Park design (Figure 7)

This student didn't use Logo for sketching his idea; but she used a part of the activity on Fractal dimensions to find out if the spots used for the park were fractal. Finally she developed another proposal with the "spots" that she has been working on and that were measured using the knowledge from the fractal dimension activity.

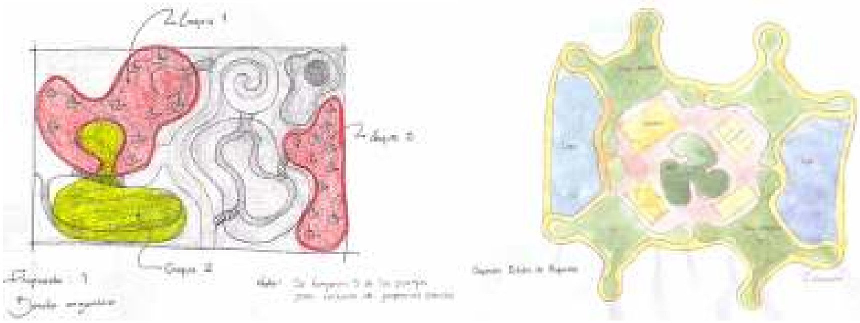

Figure 7. Rocio's work sketch and final project

5.3. Discussion and recommendations

Susana's case: There was only one participant, Susana, that didn't make any knowledge transition. Interestingly, Susana was the participant that had worked the best during the sessions. She learned quickly how to program in Logo (she was technically skillful), hardly ever made any mistakes, and seemed to have understood the knowledge on Fractals, but she didn't have a clear understanding of how to use them in her designs. We speculate that the fact that she went through the activities very quickly and didn't make many mistakes, could have hindered her assimilation of the knowledge, as she didn't spend as much time on discussion and reflection as the other participants. In this sense we could also argue that the experience of making mistakes and reflecting on “what went wrong” is as important as the discussion experience.

Success factors and recommendations

There are two factors that we consider essential for having success: 1) The content must be presented in a way that leads to meaningful knowledge for the student (meaningful apprenticeship); and 2) that students should be given the opportunity for constructive activities that facilitate the building of connections between the new and the previous knowledge as well as the transference of the new concepts to other areas of knowledge.

When applying the activities, it is important to establish the initial conditions (to work individually, in pairs or in small groups); to have control upon the data that will be provided to the students; to establish the rules for discussions and to watch over all the interactions inside the microworld.

Finally we observed the importance of having short activities. In the interviews and on the video, we observed that when an activity lasted too long, students got tired and felt disappointed. In contrast, when the same activity was split-up as a group of activities, students felt successful when they completed each part.

References

Castellanos E & Sacristán AI (2003), *Logo as a tool for introducing Fractal Geometry to students of Graphic Design*, Eurologo’2003 Proceedings: Re-inventing technology on education, Cnotinfor, Lda. Coimbra, Portugal, 306-316

Díaz Barriga F & Hernández G (1998), *Estrategias Docentes para un Aprendizaje Significativo: una interpretación constructivista*, Mc. Graw Hill, Mexico

Frauenstein T (1993), *Process-oriented Applicative Programming,* in G. Hommel G (ed) Forschungsprojekte des Graduiertenkollegs Kommunikationsbasierte Systeme, TU Berlin, 73-84

Hoyles C & Noss R (1987), *Synthesizing mathematical conceptions and their formalization through the construction of a Logo-base school mathematics curriculum*, International Journal of Mathematics education in science and technology 18 (4), 581-595

Hoyles C & Noss R (Eds) (1992), *Learning Mathematics and Logo*, MIT Press, Cambridge MA

Papert S (1980), *Mindstorms: Children. Computers and Powerful ideas*, Basic Books. Inc NY

Piaget J & García R (1982), *Psicogénesis e Historia de la Ciencia*, Siglo XXI, Mexico

Vygotsky L (1978), Mind in Society: The development of higher psychological processes, Harvard University Press, Cambridge, MA