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Geometry & Decorative Arts in Children's Creativity

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Abstract. In this paper, we present the main results of research where empirical data was obtained from the use of geometry and decorative arts with 72 children from the early grades of Primary School over the course of one year. This work is part of a research project that we are coordinating whose objectives are to know, understand and explain how a child in the early school years perceives its environment and explains it using concepts from geometry and decorative art. Children perceive their environment, compare it to what they already know and confer significance on the various scenarios that surround them. This creativity tends to diminish during the school years. With the intention of avoiding the loss of this seemingly innate talent, we initially developed our work with grade-school children joining together geometry and decorative art, leading the children to learn ideas about geometry and isometry, sharpening both their perceptions and aesthetic sense, valuing art and nature and developing their creative talent.

Key Words: Geometry, Decorative Arts, Creativity of Children

MSC 2000: 00A35, 51-01

1. Presentation

In everyday life, children perceive their environment, obtain information and select from it. Then they compare it to what they already know and, after assimilating new information, confer significance on the various scenarios surrounding them. Children are always involved in interactive research about everything within their grasp. Their imaginations surpass the limits of the image, leading them to create symbols or objects and to shape ideas, giving form, color and sense to the world in which they live. They act spontaneously in order to see what happens and, above all, select whatever contributes to an increase in their knowledge [2, 9, 16]. This complex process peculiar to the human mind basically passes through three stages: perception, comprehension and signification. This means that each sensation or perception that the child takes in from the environment generates imagination and ideas in his/her mind that, starting

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from the comprehension that he/she already has, may be transformed into significance, a mental model that results in understanding [10, 15]. Mental models, or representations of the world to which we belong, enable an ever increasing capacity to express and reproduce in various ways; meaning that the child creates and re-creates models in his/her mind that can allow him/her to establish ways of being and acting [4].

The child perceptual field widens in accordance with its surroundings, allowing the child to construct concepts. These concepts are ruled by mechanisms of memory wherein the images of the senses are fixed in place and remembered by association with each new experience. Each child learns in his/her own manner, style and rhythm. Learning styles can be represented by four categories: visual (centered on visualization), auditory (centered on hearing and listening, reading/writing (text based) and active (learning by doing). Perception, comprehension, signification of concepts; i.e., the effects of learning are retained in the memory.

This process is reversible after a time since it depends on external and internal stimuli. It is worth noting here that knowledge flourishes to the degree that different events or perceived information can be represented by means of symbols and messages, mainly influenced by external stimuli occurring with teaching methods or processes or from the transmission of knowledge [7, 17].

In most cases, children are inserted into the knowing and doing of things. However, when they end up going to a school, its hermetic contents and traditional teaching methods, concerns about rules, convention and program curricula result in the fact that there is not enough time left to stimulate perception, comprehension and representation in any integrated way that makes sense to children. Formal schooling offers little opportunity for children to develop their creative talents. Such schooling implies a submissive existence that contributes to the destitution of ideas of children, and their natural creativity tends to diminish or become obscured during their school years.

In the curricular structure, *Mathematics* and *Design* are independent disciplines and, in general, are treated as if there were no connection between them. In Primary School, for example, activities in Design are often playful and not connected to Mathematics; the emphasis is on arithmetic, rarely on geometry. This frequently leads children to respond to specific questions in a certain, standard way, without considering the amount of information that they have already received from the outside world, much less their particular capacities. This in turn leads to passivity and inhibition on the part of the child in his/her resolution of significant questions and or problems. This passivity ends up becoming an obstacle that holds the child back, especially when learning mathematics. According to [18], several studies show that during the grade school years, children tend to apply strategies in a superficial way when solving problems, leaving out their knowledge of the real world.

According to [6], "children enter school with a great deal of informal or intuitive knowledge of mathematics that can serve as the basis for developing understanding of the mathematics of the primary school curriculum. Without formal or direct instruction on specific number facts, algorithms, or procedures, children can construct viable solutions to a variety of problems." [8] defends the idea that the manual arts contribute to the development of creativity, principally when the child uses his/her imagination as the means for putting creativity into action. Creativity emerges, for example, when a child seeks to transform scrap materials into useful or ornamental objects. The manual arts require imagination 'to give existence to something'. By practicing drawing, a child signals its imagination. Each trace, form and color used tends to reveal how the child associates his/her ideas.

Thus, in primary education mathematics integrated with design can contribute to this 'flourishing' since the activities involved in the process can lead the child to understand a situation or context and acquire the mathematical language that permits him/her to describe, represent and solve a real-life situation or context and to interpret/validate the result within this same context. Since imagination and creativity are inherent in children, it falls to the school to provide conditions that do not inhibit these talents but rather ones that enable a flourishing of knowledge and ability, applying them to the benefit of the children own nature.

With the intention of avoiding the destruction of this innate talent in children, we conducted a project with children in the early grades of Primary School, joining together geometry and decorative art design. t is worth noting that using elements from the surrounding environment and orientation in drawing techniques, we led the children to learn ideas about geometry and isometry, sharpening both their perceptions and aesthetic sense, valuing art and nature and developing their creative talent. In these terms, our objective in this research was to learn, understand and explain how a child in the early school years perceives his/her environment and how he or she explains it using concepts from geometry and isometry.

2. Research lines

In order for us to learn, understand and explain how a child in the early school years perceives his environment and explains it using concepts from geometry and decorative art, we divided this research in two stages: one to affect the classroom experience and the other to analyze the data, elaborated as follow:

First stage: Classroom experience

First, we designed didactic support material for the teacher, based on Biembengut's research performed during the 1990s and 2000s [5, 3]. Next, we invited some teacher volunteers to participate in the course to know the material; their reflections and suggestions contributed to the improvement of the material. Lastly, we chose a public school where two of these teachers worked, applied the course and asked the teachers to provide us with information during the process. The teacher support material was made up of three stages: Strips, Rosettes and Mosaics, sub-divided into 20 activities, in which basic concepts of geometry and isometry, including linear measurement of surfaces were integrated with decorative art or ornaments were developed.

Ornament is the art of composing an adornment with a generating element or motif that repeats itself, obeying some form of logic or rule, a method that in mathematics is called isometry. The grammar of ornaments establishes the classification of isometric groups, emphasizing the mathematical properties of translation, rotation, reflection and reflected translation or glisso-reflection. The concept of isometry can be found in ornamental designs in the textiles, utensils and wall patterns of numerous cultures. Given a figure (a smaller part of a shape) and applying one or more properties of isometry, we obtain an ornament. In mathematics, we consider three types of ornaments: decorative strips, in which the design repeats itself indefinitely inside a strip described by two parallel lines; rosettes, in which repetition occurs within a region limited by space; and mosaics, in which a figure repeats itself in such a way as to cover the whole surface [1].

In designing this material, we appropriated the three phases of the cognitive process in order to adapt procedures to the learning of geometry and design of decorative art in primary school teaching. The procedures used in primary education are synthesized into three phases that will be called *perception* — stimulation of observation and interest; *comprehension* —

an increase in knowledge and signification; and *modeling* — association of ideas – creativity. These procedures were realized in flexible phases in a circular, give and take, process.

In order to stimulate observation and heighten interest, activities were promoted which involved placing the children in contact with nature (its beauty, charm and harmony) and by using art that illustrates the environment, thus stimulating perception. Increase in knowledge was based on teaching children about these elements of nature and the arts in such a way that they lead the children towards comprehension of how geometry and isometry are present in the environment. To encourage association of ideas, we guided them and represented to them drawings or elaboration of the elements in objects they observed that interested them. About 72 children from two public schools participated in this research, sub-divided into three classes: two from the 1st grade (25, 26 children, respectively) and one from the 2nd grade of elementary school (21 children).

It is worth noting that the teaching material only served as a guide for each teacher to teach geometry, isometry and the design of decorative art, while at the same time stimulating the art of observing, respecting and creating. The manner and creativity necessary for conducting the activities with the children remained within the domain of each teacher.

Second stage: Analysis of research

For the purposes of analysis, we adopted "conception of geometry and isometry" as a category of analysis. By conception, we mean the capacity that each person has to conceive or create ideas, abstract, form mental models and further, comprehend a subject, all resulting from his/her interaction with other people. According to [4], each person processes information in a certain way, according to their own function. Person processes information received from his/her surroundings. The information from those surroundings is added to what the person already possesses, incorporated according to his/her values and origins of his/her knowledge.

In the representation or reproduction of the decorative art (strip, rosettes or mosaics), for example, the use of geometry and isometry concepts requires a series of procedures that pass from careful observation of the situation to be represented, through interpretation of the realized experience, into grasping the significance of what has been produced. This model is the expression of their first perceptions of reality and their desire to make application of those perceptions in the representation, i.e. conception. Every creative activity originates first in the relation between the individual and the objective world of work and secondly, in the connections between the individual and other human beings [9].

In order to perform an analysis of the conception of geometry and isometry of children, we based our obtained data on: (1) the work made by these children; (2) three evaluations (written and oral) and (3) the actions and motivational state of the children, observed during these classes by their teachers. To support this analysis, we relied on the theories of several authors who work in neuroscience, among them [7, 10, 11, 15, 16, 17]; cognition [6, 8, 9, 14]; mathematical modeling [4] and creativity of the children [1, 2, 3, 12].

3. Synthesis of the teaching material

To illustrate this, the following presents six activities from each of the three stages (*Strips*, *Rosettes* and *Mosaics*) that make up the teaching material. The numbering, as well as the stages, does not correspond to the sequence or the form in the material. This is because work with children required accurate detailing and orientation. For ethic reason, appears only child's first name. Each child did at least two works or decorative art in each activity. So, as we had 72 children, participants of that project, we analyze more than 500 works.

First stage: Strips and first concepts

Activity 01

- We make a pattern from construction paper, place it on another sheet of paper and trace around their pattern. Next, we slide the pattern over and trace it again. This 'sliding is called' *translation*. Then, we mark some points on the two figures (in a convenient way) and draw line connecting them. The lines we get are called *segments*.
- We extend the two segments so that they are parallel and then repeat the pattern between these two *parallel segments* in such a way that each figure keeps the same distance from the other, creating a translation. We have thus created a decorative strip.

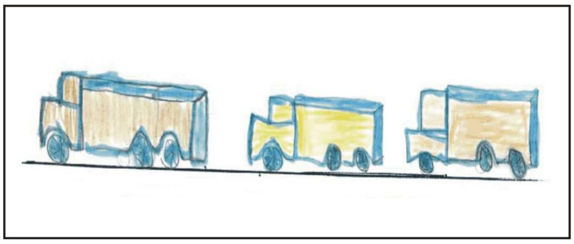

Figure 1: Sandra's work

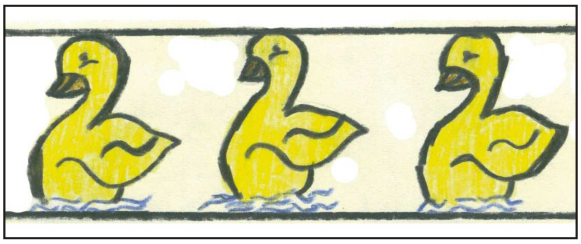

Figure 2: Tatiane's work

Before doing these activities, the children observed various decorative arts in their surroundings and thus prepared designs over reticulated strips, in order to stimulate logical thought, and the notion of measurement and order. The measuring that children used in preparing their strips helped develop in them the concepts of isometry (translation and reflection) and geometry (points, segments, parallels and perpendiculars) without any formality other than the ideas themselves. It's worth restating that each child created his/her own figure and was able to observe the validity of the mathematical concepts as demonstrated in what he or she would go on to create.

Activity 02

- We take a rectangular sheet of paper and fold it in the middle. Next, we draw a line on the fold. This line (or segment) is perpendicular to the upper and lower edges and parallel to the other two edges.
- With the paper folded, use scissors to cut designs anywhere on the paper, making sure not to cut completely through the fold.
- When we open it, we get two equal but inverted figures. The figure obtained corresponds to the observed image of the initial figure, as if the object were in front of a mirror. This movement is called reflection.
- Then we take another rectangular sheet of paper and we fold it as if it were an accordion.
- Next, we take a scissors and we cut it as we see fit. By stretching it we have another decorative strip.

In this phase, although the students focused on obtaining symmetry, in the sense of balance in the composition of decorative strips, the mathematical concepts learned were explicit. Furthermore, following [9], they achieved a harmonious composition and produced recognizable and enchanting hybrids.

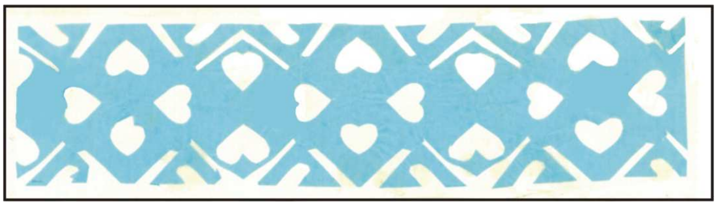

Figure 3: Vanessa's work

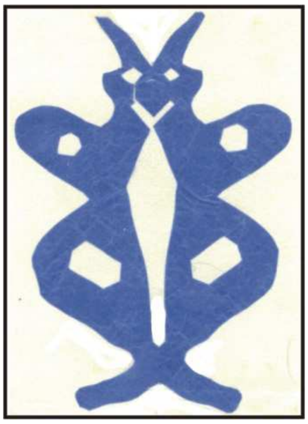

Figure 4: André's work

Second stage: Rosettes and concepts of rotation, circumference, angle, quadrilateral

<u>*Activity 03*</u>

– We again trace the pattern of a figure over a sheet of paper (we can use the same pattern as used before). Fixing the pattern at point O, we're going to rotate it clockwise or counter-clockwise, tracing it again. This tracing is called a *rotation*.

– Then we take a square sheet of paper and fold it along one of its diagonals to form two triangles. We make a line along the fold. This line can be considered the *diagonal* of the square sheet of paper. Next, we make another fold in this sheet, in such a way as to get another diagonal. With this, the sheet is divided into four equal *triangles* (of the same size).

– Next, we trace the pattern in each of the two triangles of this sheet, in such a way as to keep them in the same position (the same angle) as before. Completing the figure, we obtain a *rosette*.

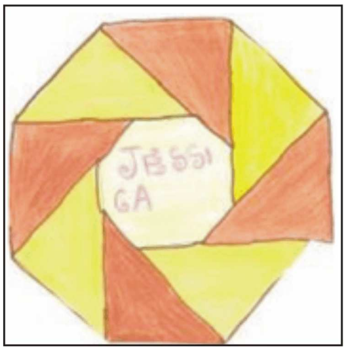

Figure 5: Jéssica's work

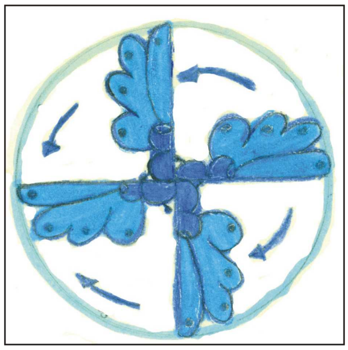

Figure 6: Vanessa's work

In this stage, ideas of movement were included – rotation and angle. This experience demanded perception of this movement by the students and searching for a way of modeling or expressing a certain balance in the composition, a rosette in this case. According to [11], knowing is doing, and doing is knowing. And the act of knowing produces a world; and this knowledge is associated with cognitive roots.

Activity 04

- We can make a rosette another way. With a circular object, such as a bottle cap or aluminum can, we wrap a piece of paper around it and get its circumference.
- By cutting the sheet on the line marked circumference and folding the sheet (circle) of paper in half a few times, the sheet will be divided into various equal parts sectors.
- In each part (sector), we apply the pattern and get a rosette, or rather, the entire figure rotates at a certain angle around a point O (which may or may not belong to the figure).
- We observe that in the strip, using translation the figure may have reflection and/or rotation, as well. In the rosette, the movement is always rotation, but the figure can make a reflection. The movements of translation, reflection, and rotation are properties of isometry. Isometry means that in effecting a movement in a figure, neither its shape nor its size varies.

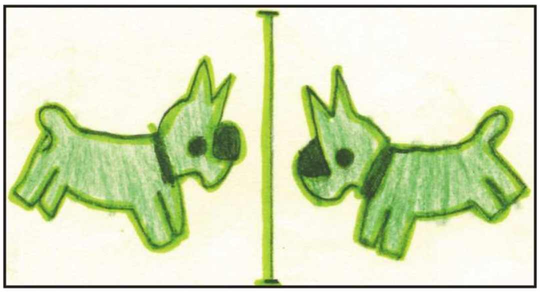

Figure 7: Jéssica's work

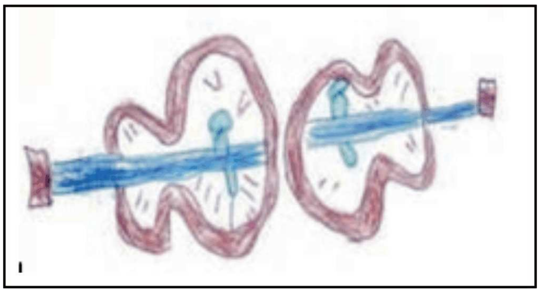

Figure 8: Vanessa's work

Using these activities, the concepts of angle, circumference, circle and quadrilateral were developed. Using paper and scissors, we also made paper cut-outs. Visits were made to architectural sites and churches to observe stained-glass windows and chandeliers, and observations were made of familiar handicrafts like crochet, knitted woolen clothes, and embroidery. Appreciating activities like these can help valorize art, architecture and culture.

Third stage: Mosaics and concepts of outlines and area

Activity 05

- The ideas of translation, reflection and rotation are not only present in decorative strips or rosettes that appear in wall decorations, stained-glass windows or the work of craftspeople; but they can also appear in the composition of another ornament called *mosaic*.
- To make a mosaic, we first trace a pattern, called an outline. The outline can have the form of a *square*, *rectangle*, *triangle*, *hexagon*, *trapezoid* or *parallelogram*.
- Next, we attach a pattern to the outline and by applying one or more properties of isometry (translation, rotation and reflection) we have a *mosaic*.

At the beginning of this exercise, each child had better motor coordination, thanks to representations already made. He/she also expressed better designs by making use of symbols whose sense had been made apparent to them. According to [14], the symbol is an individual elaborated sign and very often understood by the child since the image is reside in his or her memory. The communication between them helps a lot. According to [7], "communicating about problem solving: when kids listen to each other, they understand it better than when they hear it directly from me. It makes more sense to them".

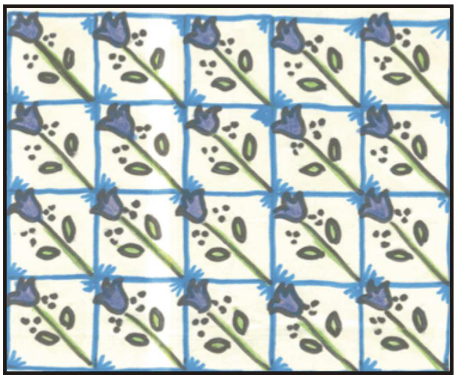

Figure 9: Gislaine's work

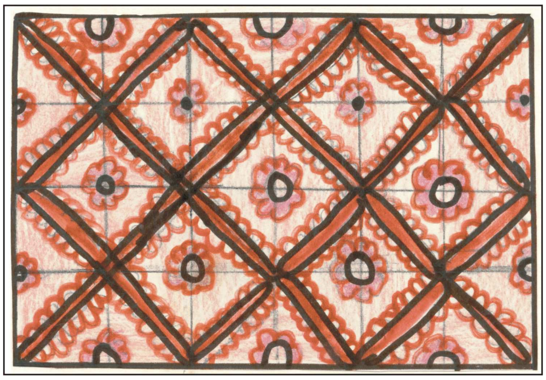

Figure 10: Josiara's work

Activity 06

- *How to make decorative art like* ESCHER*'s*[1]? To do this, we first draw a *rectangle*. Next, we remove a part of any side by making some cuts.
- In a suitable way, we then glue these cut parts onto the sheet of paper, conforming to the following guidelines:
- If the part removed is passed or translated to the other side of the rectangle, the area will not be altered. Rather, the *area* of the figure obtained (in this example, the figure of a fish) is the same as the initial rectangle.
- Then we make an outline of rectangles. After that take out part of each rectangle from the outline and put it on another part of the outline. For this step, we make use of the patterns from the parts that will be taken from one side and put on the other.
- We see that the 'parts of the figure have undergone permutations; the rectangle is being deformed but the area remains the same.

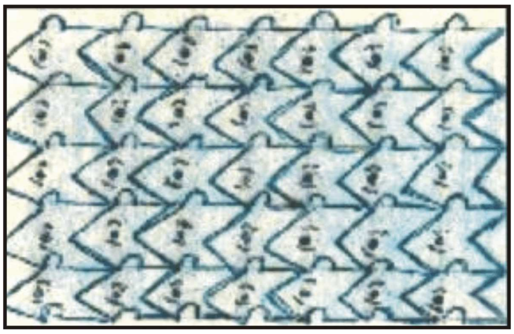

Figure 11: Thiago's work

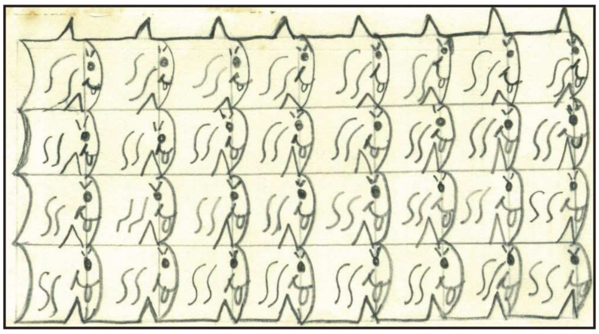

Figure 12: Tatiane's work

The work of students in this stage suggests that they improved their conceptions of mathematics developed during this experience. It contributed to overall improvement in the measure to which the activities appealed to their interests. According to [14], interest, self-esteem, spontaneous inter-individual values and intuitive values seem to be the principal crystallizations of personal affective life at this level of development.

[1] Maurits Cornelis ESCHER (1898–1972)

4. Main results and conclusions

As we have said, this work sought to lead children to observe the decorative arts and nature and to express themselves through drawing, i.e. we sought to stimulate the perception that they were able to generate in their minds both imagination and ideas that, starting from comprehension and understanding, can be transformed into knowledge – conception. Conception permitted them to form images and concepts, create objects, and give color, form and sense to the world that we live in. Though perception is not the only source of knowledge it is nonetheless essential to the first description of our surroundings, allowing the mind to decode them and enable representations.

In this way, once perception and comprehension of the decorative art that surround them were stimulated in children, we sought to promote activities that enabled them to surpass learned images, leading them to conceive other images, delineate symbols, and sharpen the creative and imaginative senses. he works made by the children allowed us to perceive how mathematics is reflected in design and how design is reflected in mathematics. Indications suggest that the more the children experimented, the more they revealed the possibilities of this proposal. At the end of each Stage, we applied oral and written evaluations in order to verify the conceptions of the children in relation to the concepts of geometry and isometry developed during the process. Each evaluation had two parts: in the first, each teacher took his/her group of children to some environment (school patio, playground) or presented some material (film, magazines, images from nature or the world of art) and asked the children to identify images that suggested the mathematical concepts that had been developed. In the second part, a set of designs was presented on a sheet of paper and each child individually had to indicate the concepts in these designs. According to [9], when working with children it is valid to use metaphorical language, or to rename an object based on a perceptual resemblance.

In the oral evaluations, everyone who participated responded to the questions satisfactorily. If some children at first failed to answer a question that one child had already answered correctly, the teacher asked the question again and all answered correctly. t is worth noting here that almost all the time the children communicated their thinking in the classroom, either orally or by showing their work. hese interactions in large or small groups or during individual interactions with the teacher or another child contributed to improving and/or stimulating the conceptions. In the written evaluations, 78% of children from the 2^{nd} grade and 62% of those from the 1^{st} grade identified all the concepts developed, i.e. there was significant learning of mathematical concepts that was verified by the written evaluations designed to determine this result.

The results presented by these 72 children, joining geometry and design of decorative art, are justifiably encouraging to Primary School. Some results obtained were:

- The children accomplished all the activities proposed in a climate of motivation and interest. They were frequently asked to give their ideas, and their peers were expected to listen to and value each others ideas. Gradually, each child felt that his/her ideas were important and valued the process of doing geometry. Children might draw their decorative art or model the action or relationships with physical objects. The childrens work showed that they are creative, taking into account our own perceptions of the results demonstrated.
- Based on his/her perception and composition of ornamental design, a child can better understand mathematical concepts, improve discernment of the values and conceptions

of the past, value the abilities intrinsic to society and culture and stimulate his/her creativity.

- The conceptions of geometry and isometry began to form beginning with the teaching process used. This led to the children continually observing art in nature in his/her environment and valuing shapes, forms, colors and rhythms represented in the environment. The technique of decorative art and the concepts of geometry and isometry enhanced the childs freedom to create.
- Representations and designs of decorative art became a basis for learning symbols and formal procedures. Not only could symbols and procedures be presented as ways of representing the art that surrounds them, but the construction of procedures for using this knowledge in other situations and for other problems that may arise in other aspects of their lives also became a possibility.
- Despite all the difficulties that confront teachers, the volunteer teachers showed themselves to be motivated by both the process and the results, integrating the program as part of their curricula. The individual teachers decided what to teach, who to call on, how fast the lesson should move, how to respond to a child and so on. his encouraged understanding the process because it allowed the teacher to teach the children, and at the same time, made their own designs in accordance with their own ideas and desires.
- The school principal respected the project and demonstrated confidence in our proposal, even without having any knowledge of the topic and considering the possible problems the project could have caused for the children, or even the school. In the end, she expressed satisfaction not only with the positive results in relation to creative talent demonstrated by the children, but, and more importantly, with the fact that the work spurred a sense of aesthetics, ethics, respect for nature and culture, and the value of artisans work.

Research shows that when used together in teaching, geometry and decorative art can enable children at any level to learn and develop abilities for making use of mathematics outside of the classroom and furthermore, motivates studies that are relevant to mathematics [4, 13]. n our part, what we perceived, witnessed and verified in our work with the children and from the teachers reports is enough for us to continue believing in the creative talent in our children, based on proposals that encourage them to value customs, cultures, art and above all, to respect nature.

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