

# Visualization: The Contribution of a Mathematical Mediating Artefact for Creative Processes and Design Activities

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## ABSTRACT

Considering mathematical knowledge as an artefact that mediates social activities in the world, this paper emphasizes the contribution of visual thinking to mathematics education and extends it to the learning of design activities, especially in architectural contexts. Results from a previous research paper on architectural design, which focused on the work of some contemporary architects in their day-to-day office activities, showed the relevance of drawing in architectural practice. These results aroused our interest in researching the mediating role of drawing and its structuring effects on creative processes and design activities in architecture.

**KEYWORDS:** visualization, mathematics education, architectural design education, activity theory.

This essay presents some of the results from an ongoing research project that seeks to understand the mediating role of drawing and its relevance for structuring thought while solving an architectural problem. The most appropriate approach to begin this research draws on the recognition that drawing is frequently used to elaborate and to solve mathematics problems, especially geometry problems. We recognize that in mathematics education there are many studies that focus on the mediating role of drawing and its relevance to the mathematics classroom.

Recently, a theoretical perspective based on concepts from activity theory is being used in some mathematics education studies and in others fields of education. We seek to illustrate the role of drawing as a mediating tool for creative processes, especially in architectural design class activities.

## Visual Thinking and Visualization in Mathematics

Mathematics education researchers have emphasized distinct modes of thinking. The fundamental work of Kruteskii (1976) about the verbal/logical and visual/pictorial ways of thinking shed some light on these different modes and on the relations between them. Further studies stress the role of visual

thinking and visual representations as mediating artefacts for the teaching and learning of mathematics and the relevance of spatial thinking from early mathematical development onwards.

Smole (1996) explores the pictorial potential and its interfaces with the other intelligence components seeking for the development of mathematics classroom activities for young children's education. Arcavi (1999) argues that visualization brings the possibility to see the unseen, to think about and to develop unknown ideas and advanced understandings. According to the author, the nature of visualization is such that it takes an important role both in the practice and the research on the learning of mathematics.

Veloso (2000) and Gutierrez (1996) corroborate the relevance of visualization for the learning and teaching of mathematics and emphasize that the teaching of geometry promotes the development of visualization and representation processes. The biggest difficulties in this field, commonly expressed by the sentence "I am not able to see in space" (Veloso, 2000, 120), are perhaps due to the representations in two dimensions of the three dimensional images that we form in our minds. Gutierrez (1996) reinforces the importance to develop student's abilities to deal with the two-dimensional (2D) and the three-dimensional (3D) forms of the object. He points out

that students lack the ability to visualize; this presents a challenge to be overcome. Thus, we realize that the familiarity with different forms of geometrical representations can aid in the acquisition of the abilities which allow one to create, to transform and to analyze the images of objects.

### Visual Thinking and Visualization in Architectural Design Processes

In the architectural context, the activity of the architect is characterized by the integration of the answers and solutions to a complex problem. However, these answers are not unique and each one of them can offer advantages and disadvantages. Because of this, design processes are valued by many design theorists (Silva, 1983; Schön, 1983; Lawson, 1996). The design process is characterized as a progression that “moves on in the direction of a solution proposal” (Silva, 1983, 76) and in which uncertainties decrease and definitions increase.

According to previous research, Góes (2005) points out that it is within the design process that drawings gain relevance, as they permeate all of the architect’s activity. Drawing is essential in the architectural practice and it represents the evolution of the design process itself and, according to Robbins (1997), it indicates the mode according to which the design was conducted, tested, controlled, presented and finally developed.

When searching for the most adequate solution to a design problem, many different kinds of representations in which visual thinking and visualization are considered essential tools can be presented. For architects, to be able to see the space where they are working during a design process becomes a fundamental and necessary step in the evolution of the design itself. Therefore, visual thinking and visualization become relevant for the necessary move between 2D and 3D representations within design processes.

### Contributions of Activity Theory

According to Engeström (1999), Activity Theory has been developed through the contributions of three generations of researchers. The first generation is represented in some of the central ideas of Vygotsky, especially the idea that an activity is mediated by artefacts. The second generation is represented by the innovations proposed by Leontiev, regarding the levels of activity, and the third is represented by the structure proposed by Engeström himself, who developed a model of representation in which the mediating elements between the components of the activity are integrated in a systematic way.

For Vygotsky (2003) a human action is accomplished by three basic and necessary elements which are the *subject*, the *object* and the *mediating artefacts*. According to him, the subject is the agent who directs his actions to the object of the activity.

The *interaction* between the subject and the object, which can be a material, emotional or even a cognitive object, is always mediated by *tools*, or artefacts of mediation. The *tools* are what make the transformation of the object possible. For Leontiev (1981), the activity is socially mediated. And what regulates and guides an activity is the *necessity* of a given object.

For Engeström (1999) the introduction of the community into the structure of the activity imposes other mediating elements apart from the tools. The relation between the *community* and the subject is also mediated by *rules*, that is, by socially agreed upon norms—tacitly agreed upon or not. The mediation between the *community* and the object occurs through the division of labor. The *division of labor* allows us to perceive the hierarchical elements within a community, which express themselves in the attribution of tasks legitimated by the social milieu.

In order to think about and describe a collective activity, in which various subjects or groups perform actions not directly oriented toward the object of the activity, but instead interrelated to the activity through the division of labor, Engeström presents the notion of the *activity system* as a concept central to his analysis. Therefore, we will no longer have a mediated activity as the *unity of analysis*, but an *activity system*, in which the interaction of the subject with his community can be expressed by an interconnected network of actions collectively negotiated and distributed according to the division of labor. For Engeström, an activity system is never static. He also emphasizes the heterogeneity within the activity system and the existence of *multiple voices*, originated by the fact that different individuals have their own history and they occupy distinct positions in the division of labor in their own community. This heterogeneous environment can provoke re-orderings, renegotiations and the permanent construction of an activity system. This mobility inside the activity, and throughout its development, is motivated by *internal contradictions* in the activity system. These contradictions are perturbations or *tensions*, which are exposed through the problems found in the activity system, can lead subjects to question practices, causing ruptures that can bring expansive changes within the activity by way of proposed innovations. Within the activity system, development occurs when the contradictions are overcome.

### The Methodological Approach of the Ongoing Research

By means of a qualitative approach this research uses in-depth interviews and class observations as sources for data generation. The in-depth interviews were made with 15 design teachers from three different architecture schools from the city of Belo Horizonte, Brazil. In the group there is some variation in the amount teaching experience of the teachers selected. The interviews were recorded and later transcribed. The classes that were observed by the first author of this paper were held at the Architectural School of the Federal University of Minas

Gerais, during the second term of 2008. Altogether, ten classes were observed and video recorded during the coverage of called interior design. During these classes the focus of the observation was on a design activity developed by a pair of students while they worked on their design for a cafe located inside a shopping center in the city.

## Partial Results

For architecture students, visual perception and visual imagination have often been considered intuitive abilities that are usually taken for granted. However, present research has shown how what some design students and teachers say reveals that—contrary to what is commonly assumed—architectural students have difficulties in dealing with the representation and visualization of objects. Some of these difficulties, as expressed in teachers' statements, are presented below:

*We began to realize that they could not see . . . the space. I've noticed . . . that they do not know how to design. They design in 2D, right? But they have to get free from this 2D vision to reach spatial vision.*

*It ends up as my responsibility to help them to see . . . because the drawing does not represent their ideas. A student will draw something and say, for example, 'I want motion in my architecture and the graphical representation has no movement at all!' The speech is very different from the image.*

*One of the difficulties that students have is exactly spatial abstract vision.*

The difficulties pointed out by several teachers above are also apparent in the class observations as well. Activity theory provides this research a lens that could help to improve our understandings of the teaching and learning processes inside design classrooms. Using its conceptual framework, the classes observed were considered an activity system. To analyze this system we considered that there were two other related activity systems within it, a *teacher activity system* and the other a *student activity system*. In the teacher activity system the teacher was considered the subject, and in the student activity system the pair of students was considered the subject. Both activity systems worked dialogically and had the same outcome as well: the cafe design. When analyzing these activity systems, it was possible to identify some internal contradictions that promoted expansive learning in the two students. In both activity systems, drawing and the different forms of representation (2D and 3D) were considered mediating artefacts that were able to connect the subjects and the objects in each of the activity systems. As mediating artefacts, drawing and the different forms of representation (2D and 3D) took a relevant role within the activity system, both for the transformation and construction of its outcome, and for the promotion of expansive learning in the students. Although there is not enough room to present complete analysis in this essay it is important to say that, of all the evidence garnered from the

study, one that needs to be emphasized is the mediating role of drawings and the different forms of representation (2D and 3D) as a kind of contribution to visual thinking while seeking a solution to a design problem.

## Conclusions

Some results of this research on design instruction and learning led to a dilemma: on one hand, they show that architectural students have difficulties in dealing with the representation and visualization of the object with which they are working, on the other hand, they show the relevance of drawing and the different forms of representation on the construction of the object, that is, on the design processes themselves.

Considering these results, we argue that these difficulties are similar to the ones identified by mathematics educators and that the development of visual thinking at the elementary school level, as proposed by math educators, can be an important contribution not only for mathematics students but also for all fields that involve creative processes and design activities.

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