

# Eliciting Students' Visual-Spatial Thinking Processes in an Art Studio

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## Abstract

We investigated seventh-grade students' visual-spatial thinking processes in an art studio in which students were engaged in observing minimalist artists' artworks and creating their own artworks, as a possible connection between visual arts and mathematics education. The findings of the study shed light on further exploration of possible connections between visual arts and mathematics education and provide a theoretical basis for STEAM (Science, Technology, Engineering, Arts, and Mathematics) studies.

## Introduction

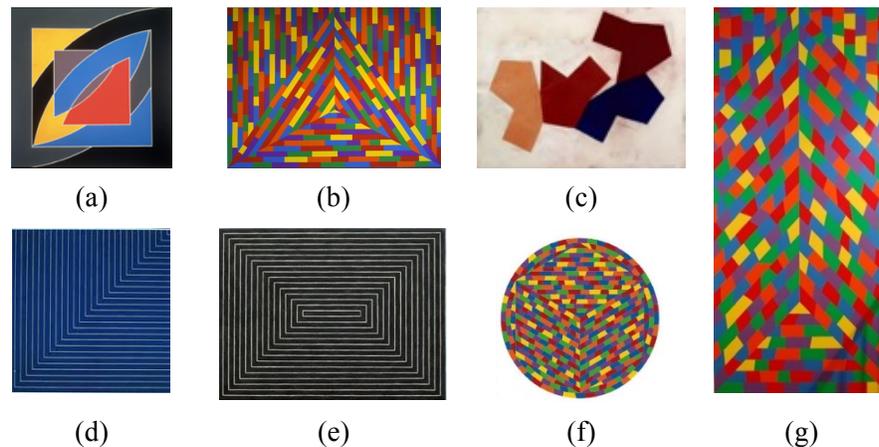
How visual art could be integrated with mathematics or other learning fields is debated among educational research community. In the OECD report on the impact of arts education, researchers discussed the lack of information (how the study was conducted, its theoretical background) in the studies on arts integration. They suggested conducting studies with a theoretical background that provide concrete outcomes of this integration and explain at what conditions they were observed [6]. Some studies also put importance on investigating congruent cognitive processes between visual arts and mathematics [1] [2]. What congruent cognitive processes exist between visual arts and mathematics is a crucial question to take into consideration. In one of the recent studies [2], visual-spatial thinking was proposed as a connection between visual arts and geometry, which is also the focus of the current study. Another crucial question is how students' thinking processes could be explored in the environments involving art making. Studio Thinking [3] was proposed as a framework based on thinking dispositions to design visual arts courses and to understand students' thinking processes. In this regard, Studio Thinking could be used as a tool to make students' visual-spatial thinking visible in an art studio.

The aim of this study was to explore possible connections between visual arts activities and mathematics in the art studio context. This paper reports a case study from a larger research project that investigated intersection of mathematics and visual arts education. For this purpose, we adapted the Studio Thinking Framework into a specifically designed studio-work process. In the current study, we present evidence of students' visual-spatial thinking arising from one of those studio-works conducted with middle school students. In designing the larger studio-work process, we derived several pedagogical principles through (1) the use of Studio Thinking Framework (2) use of Minimalist Artworks that is one of the visual art contexts with explicit use of geometric shapes and forms (3) studies on visual-spatial thinking. These pedagogical elements were brought together in a way to elicit seventh-grade students' visual-spatial thinking, which was regarded as one of the crucial abilities in mathematical learning domain and as an overlap between visual arts and mathematics, especially geometry [2].

## Method

Participants of the study were six seventh-grade students in an art studio of a public school. The data sources of the study were produced through stimulated recall interviews with participants, video recordings of studio-work process, students' documents (written notes, sketches, artworks). Interviews and studio-work process were both audio and video-recorded.

Studio Thinking Framework describes several habits of mind that are taught in the art studio (e.g. observe, envision, explore, develop craft, understand art world) and describes three structures of the studio including (1) demonstration (giving lecture and/or introducing artworks), (2) students-at-work (creating artworks), and (3) critique (explaining and evaluating artworks). We adapted it to the context of the study through deriving six interconnected principles from the framework: (1) Introducing minimal artworks, (2) Asking questions that prompt students to observe artworks, (3) Asking students to create their own artworks, (4) Asking questions that prompt students to envision, (5) Encouraging students to sketch for exploring new possibilities, (6) Encouraging students to reflect on their own and others' artworks. In this study, students were basically asked to find embedded and hidden shapes during observing the minimalist artworks individually and with their friends (see Figure 1), to create own artworks through hiding or embedding shapes, and to explain their artworks to their friends. To analyse students' visual-spatial thinking, studies on spatial thinking [4] [5] were used as a guideline.



**Figure 1:** Minimalist artist' artworks: (a) Frank Stella (*River of Ponds*, 1971), (b) Sol LeWitt (*Wall Drawing #1113*, 2003), (c) Mel Bochner (*Four Shapes*, 1976), (d) Frank Stella (*Hampton Roads*, 1961), (e) Frank Stella (*Tomlinson Court Park from Black Series*, 1967), (f) Sol LeWitt (*Cube Circle4*, 1980), (g) Sol LeWitt (*unknown*).

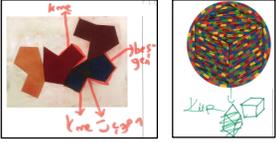
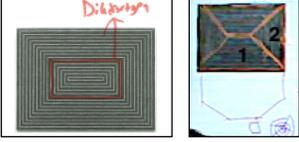
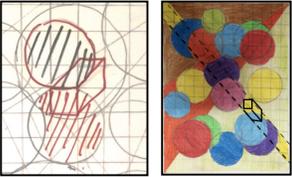
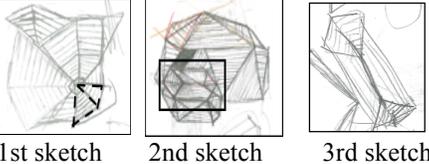
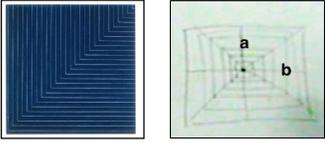
## Findings

Students' visual-spatial thinking processes were presented concerning interrelated pedagogical principles that were derived from the Studio Thinking Framework. Table 1 presents examples of the students' thinking processes. The first principle is *introducing artists' artwork with different characteristics* (embedded and hidden 2D and 3D geometric shapes, shapes from different perspectives, figures perceived as both 2D and 3D). When students were introduced these artworks and asked to observe them, they disembedded geometric shapes (e.g. pyramid, cube, triangular prism, sector, squares) in the artworks, identified them as real-world object (e.g. a path), identified them from different orientations or perspectives, used spatial proportional reasoning in the artwork with growing squares and rectangles, decomposed shapes. Their thinking processes were changed according to the way of observation: observing artworks individually and with friends. Students mostly perceived two-dimensional shapes rather than three-dimensional shapes during individual observation of artworks.

The second major principle is *asking questions that prompt students to observe artworks* (e.g., What shapes do you see?, What else do you see? and Do you notice a new geometric shape?). When the researcher asked them, students made use of visual-spatial thinking such as recognizing geometric shapes through disembedding and embedding, identifying shapes as real-world objects, identifying shapes based on their properties, and decomposing shapes. For example, during group observation of artists' artworks researcher asked students to explain what shapes they saw. They identified rectangles in the artwork.

When the researcher asked them what else they see in the artwork, they tried to realize new geometrical shapes such as a pyramid, triangle, quadrilateral, octagon, as well as they identified it as a path (real-world object).

**Table 1:** Students' Visual-Spatial Thinking Processes Regarding Studio Thinking

Visual-Spatial Thinking Processes	Students' Representations	Written Notes and Quotations
Decomposing, Disembedding <b>[Introducing artworks]</b>	 Hidden      Embedded	-Hidden figures (Decomposing the shapes into a square, triangle, and pentagon) -Embedded figure (Disembedding two-dimensional representation of a cube inside the circle)
Identifying figures as geometric shapes and as real-world objects (a path) <b>[Observing]</b>	 Individual Observation      Group Observation	“Ali: Teacher I saw rectangles R: What else do you see? Ali: This is like a path!; but, there's a triangle. I've just seen it! [Region 2] Emre: Quadrilateral!, special quadrilateral; otherwise, it cannot be a square [Region 1]. Burcu: I saw a pyramid from top view!”
Disembedding and embedding shapes <b>[Creating artwork]</b>		“R: What did you do Burcu? Burcu: I imagined the shape of a cube. R: Where is it? Burcu: Actually, there are more. There are a lot [cubes] going on in this direction.”
Composing shapes, Transforming shapes, Embedding shapes, <b>[Exploring through sketching]</b>	 1st sketch      2nd sketch      3rd sketch	“R: Could you explain how you did it? Melek: I've drawn a lot of pyramids to hide a shape (spiral), I tried to draw a square pyramid, but I could not rotate them (1st sketch). That's why I gave up. Here (2nd sketch), I hid pyramids into a square prism. They are reverse and looking at each other. (3rd sketch)”
Perspective taking <b>[Envisioning]</b>		“R: How do you imagine it as a pyramid? Fatma: A pyramid is seen from side-view. R: How would you look from the side? Fatma: Looking from the side and the top. Ali: We stand here and are not seeing the other parts [pointing at the a and b parts]”
Identifying shapes on the basis of their properties, Recognizing patterns <b>[Reflecting]</b>	 Pyramid	“Emre: I think this can't be a pyramid anyway. It is a painting created by squares growing in certain dimensions only in a certain order. R: What makes you say that? Emre: There are two sides of the pyramid and two sides are missing.”

The third main principle is *asking students to create their own artworks by hiding shapes*. During this process, students made use of a variety of visual-thinking processes. These are disembedding and embedding geometric shapes, identifying shapes' properties, patterning, composing shapes, and transforming shapes. Beyond identification of shapes, they also actively used geometric shapes to create

their own artworks. For example, one student (Burcu) drew horizontal and vertical lines, then perceived a three-dimensional shape (cube) and nested cubes through a diagonal line. The fourth major principle is *encouraging students to sketch for exploring new possibilities* during students-at-work part (creating artwork). Students, who tended to sketch their ideas, made use of several thinking processes such as patterning, perspective taking, embedding geometric shapes, identifying shapes based on their properties, composing, and transforming shapes. For example, while one of the students attempted to represent pyramids with growing sizes in one of her sketches (patterning, transforming the size of pyramids informally), she also tried to embed two square pyramids into a square prism in her further sketch. This process could be a sign for students' conceptualization of mathematical ideas.

The fifth major principle is *asking questions that prompt students to envision* (How would you look at this pyramid?, Imagine to embed a shape into other, How would you connect two pyramids?, What would happen if you changed your viewpoint?). These questions elicited visual-spatial thinking processes such as disembedding of 2D representations of 3D shapes, perspective taking, and composing shapes. The last but not least principle is *encouraging students to reflect on their own and others' artworks* (How did you do it, Why did you do in that way? What makes you say that?, Do you have any difficulty? What shape would your friend hide?). When students were asked to explain their artworks, their ideas, and difficulties, they made explicit a variety of visual-spatial thinking process ranging from identifying shapes on the basis of their properties to transforming shapes (e.g., rotation, scaling, unfolding). For example, asking students to justify their thoughts is a crucial question to understand how students think of mathematical ideas. The example in Table 1 shows that a student (Emre) tried to justify his claim, "it can not be a pyramid," based on the pyramid image in his mind.

### Summary and Conclusions

In this study, we investigated students' visual-spatial thinking processes through several pedagogical principles and minimalist artworks. The findings indicated that the pedagogical principles derived from the Studio Thinking Framework elicited a variety of visual-spatial thinking processes. Using these principles also allowed the researchers to observe the students' conceptualizations and difficulties related to geometric shapes. This study proposes a way for connecting visual arts and mathematics to be used both in school and out-of-school contexts (e.g., museums and art-science centers). Moreover, the findings of this study could be used to design courses that integrate visual arts and mathematics. We should note that the current case study has limitations in terms of the number of participants and the number of studio works. In this sense, this study should be considered as an initial step for further exploration of the connections between visual arts and mathematics education.

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