Optical Illusions

Ricardo Galindo
Sharpview Elementary School

So far as theories of mathematics are about reality, they are not certain; so far as there are certain, they are not about reality.

-A. Einstein

INTRODUCTION

The human brain, which was originally programmed for interpreting moving 3-D objects instead of stationary images on flat surfaces, has to make sense of a world in which everyday objects are normally distorted by perspective. Unfortunately, mankind is using more and more flat surfaces, such as paper and screens, to communicate with each other, causing the human brain to make an extra effort to transform two-dimensional images into three-dimensional ideas. This seems to be one of the causes why the spatial perception of students in the 21st century seems not to be highly developed.

To confront this issue at primary and secondary schools it is essential to support subjects enabling one to 'experience' space. Learners can better acquire spatial perception if a multi-disciplinary approach is used. The geometry and art classrooms seem to be the proper environment to foster three-dimensional experiences, but it is necessary that both the art and the geometry teachers purposely focus their instruction on real experiences from our three-dimensional world.

This teaching unit has been written to make third grade students aware of the duality of two-dimensional images in our three-dimensional world, and has the purpose of introducing more three-dimensional activities in both the geometry and the art classrooms.

Because of the two-dimensional representation of our three-dimensional world, sometimes images can be visually deceptive and create what are known as optical illusions. This unit will use a number of these optical illusions to stimulate the students' awareness of our three-dimensional world. We will do this by exposing them to works of art that will challenge them to see the world from a different point of view. By talking and writing about these works of art, and by allowing the students to manipulate and even create three-dimensional pieces of art, they will learn about geometry and will make the geometric terms part of their everyday language.

UNIT BACKGROUND

Before going into the details of the unit it is necessary to explain why I decided to teach this unit, what is that I want to teach in it, and how I plan to do so.

Why

Ever since I was a third grader I loved my math classes so much that I became a math teacher as a grown up. Geometry, however, was one part of the math curriculum that I really did not enjoy. Nowadays, I fear that I could be transmitting those same bad feelings about geometry to my students, so I am preparing this unit to overcome those negative feelings and start conveying good ones to my students.

Thinking about the way geometry was introduced to me during my school years, I realized that it was just a memorization exercise. My teachers presented a figure or shape and we had to memorize its name and characteristics. I therefore found it hard to think about geometry in a logical way. Worse, still there was no connection between those shapes and real life. Due to my personal experience and after being a math teacher for several years in grades tenth, ninth, and fifth, I arrived at the conclusion that people decide if they do or don't like math in the early elementary grades. This choice is usually due to the influence of a teacher. That important decision in a student's life makes me realize the power we teachers can have in both positive and negative ways. It also influenced my decision to become a third grade teacher so that I could foster a love of mathematics early on. It is also for these reasons that I am preparing this unit: to make math fun so that students like it for the rest of their lives.

What

I decided that in order to succeed in making geometry fun, I needed to teach something I like. After considering several themes that could be used to teach geometry, I selected optical illusions.

Optical illusions are a form of art presented in such clever way that somehow it fools the human eye. For example, in one of the most popular optical illusion we either see the image of a white vase in a dark background or the image of two dark silhouettes facing each other. Another example is the image of several parallel lines that don't look parallel because intersecting lines are positioned in an inclined and alternate pattern that make them appear to be curved lines (see figure 1).

Most optical illusions are geometric in character and fairly simple, so that one can describe the illusion using the basic vocabulary and concepts used in the geometry curriculum. I think that using these images to teach geometry is more engaging than using the traditional figures and shapes included in the regular textbooks. They are more

likely to fascinate the students and for that reason I chose Optical Illusions as the theme for this unit.

After deciding on the theme for the unit, it was necessary to clearly define the concepts to be taught. One cannot pretend to use just one unit to teach the entire geometry curriculum. In order to select the topics one also has to keep in mind that geometry is just a part of the already extended math curriculum. To decide which concepts the unit will cover I found it necessary to review what should be taught during the school year. To review this and make a decision I used the District curriculum (CLEAR), State Standards (Texas Essential Knowledge & Skills -TEKS), and the National Standards (National Council of Teachers of Mathematics -NCTM). Although those standards are somehow related, one can see some differences that need to be considered while choosing the topics.

The CLEAR curriculum requires that students 1) name, describe, and compare shapes and solids using formal geometric vocabulary, 2) identify congruent shapes, 3) create shapes with lines of symmetry using concrete models and technology, and 4) identify lines of symmetry in shapes.

The TEKS establishes that at the end of third grade the student 1) uses formal geometric vocabulary, 2) recognizes congruence and symmetry, and 3) recognizes that numbers can be represented by points on a line. To achieve this, the student is expected to a) name, describe, and compare shapes and solids using formal geometric vocabulary, b) identify congruent shapes, c) create shapes with lines of symmetry using concrete models and technology; d) identify lines of symmetry in shapes, and e) locate and name points on a line using whole numbers and fractions such as halves.

The NCTM expects that students of third, fourth and fifth grade analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships, specify locations and describe spatial relationships using coordinate geometry and other representational systems, apply transformations and use symmetry to analyze mathematical situations, and use visualization, spatial reasoning, and geometric modeling to solve problems. The expectations for the students' learning are a lot more detailed in this Standard.

After comparing the different standards required for third graders and what optical illusions might offer to the geometry classroom, I decided that this unit should focus on just two objectives: 1) The student uses formal geometric vocabulary to analyze characteristics and properties of two- and three-dimensional shapes and its relationship with art and real life; and 2) The student creates shapes with lines of symmetry using concrete models and technology.

How

The details of how to teach using optical illusions are included ahead in the Implementation Strategies section and in the Lesson Plans. For now I just want to briefly describe the general approach on how to convey this topic in the classroom.

I believe that one of the secrets of good teaching is to present the information to the students in such way that they can somehow become fascinated with the material, becoming so engrossed with it that they actually end up learning it. With this notion in mind, the unit is going to be integrated into the reading, writing and art curricula, where eventually the students will learn geometry without realizing it.

The topic will be introduced in the Reading classroom. There is a book written in a third grade level titled *Opt: An Illusionary Tale*. It is the story of the birthday party of the prince of Opt, a kingdom full of optical illusions. It includes a good description of the most popular illusions and it is a great way to introduce the topic. It is such a good book that the *Reading Rainbow* TV show from PBS selected it to be included in one of their shows. The video is available and it could be used to spark their interest and grab their attention.

After watching the video and reading the book, the reading teacher should discuss with the class a couple of the optical illusions from the book that caught the student's attention, making sure to use geometric vocabulary within the lecture. Part of the lesson plans to be prepared for the unit will include a good collection of comments or remarks about the book and selecting the illusions best suited to include the geometric vocabulary.

Once the topic has been introduced in the reading classroom, the students should be exposed to a lot of optical illusions in the art classroom. Students should have access to many images that they can touch, discuss, see from different angles, and even try to copy, trace, or draw. In the art classroom at least one lesson involving the creation of an optical illusion should be arranged, just to make sure that a "hands-on" activity is included in the unit. These activities will include handling three-dimensional objects and some two-dimensional representation of them to show the relationship.

After the experience in the Art classroom, the students should have a better understanding of optical illusions, and they should be more willing to share their thoughts with the rest of the class. In the Math classroom a good review of the geometric vocabulary, like the one included in Appendix 1, should have been presented to the students, so they will be ready to include that vocabulary in the writing activity.

The writing topic will be the description and analysis of at least one of the optical illusions presented in both the reading and the art classrooms. Students will have to describe it in a prepared writing format, previously modeled by the teacher, with clear directions on how to use the geometric vocabulary. They also have to explain in their

own words what is distorted in the picture and recognize the elements used by the artist to fool the public's eyes.

In this way, by including the topic in the reading, writing, math, and art classrooms the students will understand the relationship between flat images and 3-D objects.

OPTICAL ILLUSIONS

In order to understand what Optical Illusions are, we have to go back to the concepts of sensation and perception. Our eyes have special cells called sensory receptors that can detect light and transmits a signal to the brain. The reception of the signal in the brain represents sensation. How the brain interprets these signals and makes them meaningful is called perception. Most of the time, the interpretation of the received energy is consistent with it. Sometimes, however, our interpretation is incorrect. These misinterpretations are called optical illusions.

There is no single explanation for all of the hundreds, maybe thousands, of optical illusions. In some cases, there are several reasons why the images deceive us; in other cases there is not even a scientific explanation yet. If we are going to talk about optical illusions, it is necessary to find a way to classify them.

There are hundreds of publications on optical illusions including books, videos, web sites, and more, and each one of them try to classify the illusions in a different way. One book that makes a great classification of optical illusions that a third grader could understand is *101 Amazing Optical Illusions*, by Terry Jennings. In that book the optical illusions are divided in three major groups according to the reason we are deceived: on Sight (Optical Illusions that happen because of the way your eyes work), on Perception (Optical Illusions that happen because of the way your brain interprets what your eyes see), and Optical Illusions of Movement.

A second way to classify optical illusions could be by the final product, as the one included in the website <http://www.portalmix.com/efectos/>. Even though the site is in Spanish, one can see the different kinds of illusions: Double Images (with two meanings), Geometric Images, Buildings (that challenge the laws of gravity and logic), Impossible objects (that make no sense), Camouflage (Hidden Images), Faces (hidden or composed), Letters (words), Psychedelic (things that change before your eyes), and Shape/Forms (the limits between the object and the background are not clear).

I do not intend to follow any of these classifications in trying to explain the optical illusions. This information is included just as a quick reference for teachers to be used when students follow the discussion about optical illusions. Another kind of information that could be useful for teachers is a brief explanation of some of the most common terms used in optical illusions, as the ones listed in Appendix 2, which has been taken from the website<http://www.colorcube.com/illusions/illusion.htm>.

Of course, there are more effects and explanations, as one can see in any of the references included in the bibliography, but again, this is only intended as a quick source of information for most of the regular optical illusions. A more detailed explanation of the optical illusions related to geometry will be included in the next section (Implementation Strategies) and in the lesson plans.

IMPLEMENTATION STRATEGIES

When I first came up with the idea of using optical illusions to teach geometry in third grade, the main goal was to integrate the geometry curriculum in the writing classroom. While developing the unit and trying to apply it in my current classroom I realized that the writing portion is quite challenging for third graders. It might be more adequate for higher grades. For that reason, I decided to change the focus from the writing classroom to the art classroom.

As mentioned in the Unit Background section, students will be introduced to the topic in the reading classroom through the book *Opt: An Illusionary Tale* and the corresponding video from PBS's *The Reading Rainbow*. In the video, besides the illusions from the book, there are also included explanations of the making of special effects in movies, and a great introduction to the concept of perspective in drawing. After reading the book and watching the video, the art teacher will continue exploring and applying the concept of perspective, while the reading teacher will promote a discussion about one or two of the images included in the book, like the one on page 7 of the book, where the concepts of parallel and intersecting lines, as well as length and measurement, are posed for further discussion. In Figure 1 below, for example, the parallel lines don't seem parallel because of the short intersecting lines. Trying to describe this optical illusion should force students to use geometrical terms such as "parallel" and "intersecting lines"

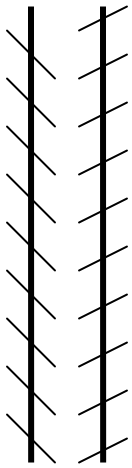


Figure 1

It is really important that the teacher challenge the students to correctly use and clearly explain as many geometry terms as possible. It is also desirable that students actually use a ruler to measure the lines to verify both the parallelism and the lengths. Students should be able then to understand the basic principle of optical illusions that vertical lines look longer than the horizontal ones due to the perspective.

Once the art teacher has finished her lesson on perspective and the reading teacher has discussed and finished the book report, the class should have access to all kind of optical illusions from books, the Internet, real paintings, and any other media. (Stereograms –hidden 3D scenes in flat pictures- are found in post cards, for example). A good selection of materials is included in the bibliography. Students will share

(both oral and written) their findings, and hopefully a geometry-rich discussion will follow. The teacher then should make sure that the students consider some optical illusions based on the flat representations of our three-dimensional world.

At this time, the math teacher should introduce (or review if that is the case) the solids. Actual construction and manipulation of solids has proven to be a very engaging activity with awesome results in the long-term understanding of their characteristics. Special emphasis should be made in the study of the cube, because later on students are going to be challenged to discover some misinterpretations in some other optical illusions like the impossible cube.

One of the experiences I had while teaching the solids was discovering that most of my third graders didn't know how to draw a regular cube. Much less, they couldn't draw or even explain the mentioned optical illusion. Definitely, the drawing of the cube has to be a lesson to be included in the art classroom, as well as the construction of one.

The concept of symmetry is used in both the art and the math classrooms. This concept could be explored in the art classroom using the well-known optical illusion of the vase and the two faces. Students will draw the profile view of a human face on a piece of paper, and then they will fold the paper and cut it tracing the face. After splitting the paper by the folding line, students will paste the pieces facing each other on a contrasting-colored piece of paper, hence creating the famous optical illusion. Although a simple activity, the teacher should seize the opportunity to emphasize that in order to get symmetry one has to start with the same shape (congruent) and that, at the end, students should be able to find a line equidistant to corresponding points.

COMMON TERMS USED IN OPTICAL ILLUSIONS

1) Blind Spot and the "Filling-in" phenomenon

Each of your eyes contains an area that has no photoreceptors because it is occupied by the optic nerve. You may not have noticed these areas because they are on opposite sides of your visual field. The "Filling-in" phenomenon occurs because the brain simply "fills in" the most probable stimulus where there is none.

2) The Blinking Effect

Despite a static image, your eyes will make it dynamic attempting to "fill-in" the clear intersections of the objects with the dark of the background.

3) Borders and Framing Color

Colors often appear brighter and more vibrant when frames border them. Black lines are commonly used to enhance colors in applications like stained glass. This tactic creates a certain effect and prevents color clashing.

4) Chromatic Adaptation

Have you ever entered a movie theater on a sunny afternoon? The room probably appeared completely dark but as your visual system adjusted to the reduced level of light you were able to see better after a few moments. This "adaptation mechanism" allows our eyes to recover from oversensitivity to particular stimuli. "Chromatic adaptation" occurs when our eyes adjust to certain color stimuli. Chromatic adaptation allows us to interpret color within the context of their surroundings. Altering these surroundings, however, can sometimes be an "eye-opener".

5) Color Blindness

Almost 10% of human males experience color vision deficiency (compared with 0.4% of females). The most common form of these abnormalities is characterized by an inability to distinguish between red and green hues.

6) Spreading and Spatial Effects

Simultaneous Contrast (colors taking on characteristics of their complement) is occasionally overridden by the Spreading Effect. This occurs regularly when there is a difference in the "spatial frequency" of objects on a background.

7) Printing between the Dots

Understanding how the eyeball interprets color is essential for creating color palettes in certain media. Color printers, which typically use 3-4 colors (sometimes more), and televisions, which use red, green and blue only, are a couple examples of devices that use dots or pixels to display color.

8) Dithering

Dithering is a color reproduction technique in which dots or pixels are arranged in such a way that allows us to perceive more colors than are actually used. This method of "creating" a large color palette with a limited set of colors is often used in computer images, television and the printing industry.

9) Recognition of Patterns

Although sometimes there are no actual shapes that appear on your eyes' retinas, your brain will somehow interpret the image as that shape if the real object merely suggests gaps in which objects should be. The brain does the rest by triggering a sort of pattern recognition phenomenon.

10) Opponent After-images

The nature of our visual system allows us to sometimes see "after-images" which appear once the original stimuli are removed. The colors in after-images are usually the opposite (complementary) colors of the original.

11) Flashing Squares

During the Optical Art (Op Art) Movement of the 1960s, artists would create all sort of puzzling effects with color. For instance, the "flashing squares" drawing seems to wobble and flash when you concentrate on one particular area of the image.

12) Contrast in Shape

How objects and colors appear is highly dependent on their context. The structural and spatial variables of a scene can influence appearance and perception.

13) Simultaneous Contrast

Identical colors appear to shift when framed by different backgrounds or patterns. This is called "simultaneous contrast" and has a variety of affects on how we see things.

14) Induction

Viewing two colors at the same time influences both of their appearances.

15) Contrast of Value

In order to maximize color recognition and text legibility, the goal is to find the optimal combination for the colors used. By varying hue, saturation and value, we can ensure good visibility with "highly contrasting" colors.

LESSON PLANS

This Unit should be taught in just one week using 45-minute periods in the reading, art, math, and writing classrooms. The suggested order for the lessons is shown below, but teachers may change it according to their availability.

Lesson	Classroom	Topic
1.	Reading	Reading *Opt: An Illusionary Tale*
2.	Reading	Watching the video *Opt: An Illusionary Tale*
3.	Art	Perspective
4.	Math	Basic Geometry Vocabulary
5.	Art	Optical Illusions
6.	Writing	Describing Optical Illusions
7.	Art	Symmetry
8.	Math	Symmetry

Lesson Plan 1: *Opt: An Illusionary Tale*

Objective
The topic of Optical Illusions will be introduced to the students. They should understand that sometimes our eyes could be deceived.

Resources
Book: *Opt: An Illusionary Tale* by Airline and Joseph Baum.
Video: *Opt: An Illusionary Tale* from The Reading Rainbow Collection

Time Required
Two 45-minute class periods

Materials
Rulers

Procedure
The order of these two lessons should be decided by the teacher depending on his or her preference for the use of the video: it can be used before reading the book to ignite the students' interest, or after reading the book to check for understanding. The reading of the book should be a read-out-loud activity, making sure that students have plenty of opportunities to see the images and comment about them. Also, students should be able to use their rulers to verify length or parallelism in some of the images.

After watching the video and reading the book, students should pick their favorite optical illusion and should be able to share with the class why they like it and how their eyes were deceived. Teacher should be available to introduce the proper words to describe them.

Evaluation
Students will draw and color their favorite optical illusion and will reflect in their journals their thoughts about the topic.

Lesson Plan 2: Perspective

Objective
Students will understand the concept of perspective in drawing. They should be able to draw a road using the horizon line and different sizes of the same object.

Resources
Video: *Opt: An Illusionary Tale* from the Reading Rainbow Collection

Time Required
One 45-minute class period
Materials
Rulers
Paper

Procedure
Watch again the part of the video where the artist explained the procedure of drawing in perspective. Make a sample on the board and ask students to tell the procedure again. Once the students are comfortable with the theory, they should try to draw their own perspective. Make sure that students understand that perspective is one of the reasons why sometimes our eyes play trick on us.

Evaluation
Students will pick the three best perspectives of the class.

Lesson Plan 3: Basic Geometric Vocabulary Review

Objective
Students will review all the geometric terms learned so far in school.

Resources
Textbook
Vocabulary List

Time Required
One 45-minute class period

Materials
Rulers
Paper

Procedure
Ask the students for all the words they know related to geometry and write them on the board. Ask the students to say in their own words the definition of some of the terms. Pick some students to draw on the board some of the terms. Distribute the vocabulary list (Pictionary) as the sample included in annex 1, and ask the students to complete the remaining drawings.

Evaluation
Students should complete all the drawings for the vocabulary list.

Lesson Plan 4: Optical Illusions

Objective
The topic of optical illusions will be discussed in detail with the students. They should understand how our eyes are deceived and what techniques the artists use to create some of the effects.

Resources
Reproductions of several optical illusions (see bibliography)

Time Required
One 45-minute class period

Materials
None

Procedure
Either in the hallway or in the classroom, the teacher will set up all the available reproductions of Optical Illusions like an art gallery. The teacher will model the kind of comments that should be done with one piece. He or she should be sure to model and ask the students to include as many geometric terms as possible. The discussion should be about what the effect is that deceives our eyes and how we can fix it. After modeling a couple of Optical Illusions, the students should be divided in small groups (3 or 4 students per group) and they should visit the gallery and spend about 3 to 4 minutes talking among them about each of the optical illusions.

Evaluation
Students will reflect in their journals their thoughts about the discussions with their peers.

Lesson Plan 5: Describing Optical Illusions

Objective
Students will use the geometric vocabulary to describe optical illusions.

Resources
Reproductions of Optical Illusions

Time Required
One 45-minute class period

Materials
Paper and Pencil

Procedure
Using the same reproductions of optical illusions from the previous lesson, students should pick one of them to write about it. Students will fill out a graphic organizer with the main geometric terms that could be used to describe the optical illusion. Words that describe location (under, above, etc) must be included in the organizer. Using a rubric for three paragraphs students should describe 1) what they see, 2) what is "wrong" with it, and 3) how it can be fixed.

Evaluation
Students should turn in their papers and their graphic organizers.

Lesson Plan 6: Symmetry

Objective
Using an optical illusion, students will discuss the concept of symmetry in both the art and the math classroom.

Resources
Reproduction of the Optical Illusion of the vase and the two faces

Time Required
Two 45-minute class periods

Materials
Paper and Pencil
Scissors
Rulers

Procedure
In the art classroom students will create the optical illusion by tracing the shadow of a peer profile in a piece of white paper. That model will be used to cut two identical faces and then paste them one in front of the other on a dark piece of paper.
In the math classroom students will create the optical illusion by using the same profile from the art activity, draw the axe of symmetry and measure the same distance to both sides. A discussion about these procedures should clarify the concept of symmetry

Evaluation
Students produce two optical illusions using the concept of symmetry.

APPENDIX 1

Vocabulary Sample List

Angle

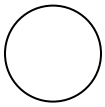
Apex

Area

Array

Base

Center

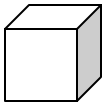
Circle 

Circumference

Cone

Congruent

Coordinate

Cube 

Cylinder 

Degree

Diameter

Edge

Endpoint

Equilateral

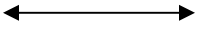
Face

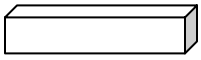
Geometry

Hexagon 

Intersect

Kite

Line 

Prism 

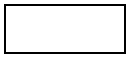
Pyramid

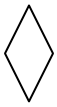
Quadrangle

Quadrilateral

Radius

Ray 

Rectangle 

Rhombus 

Right Angle

Sides

Segment

Solid

Sphere

Square 

Symmetry

Three-dimensional

Trapezoid 

Triangle 

Two-dimensional

Vertex

Volume

BIBLIOGRAPHY

Editor's note: Annotations were not available by time of publication.

All the books, websites, and videos included in this bibliography basically provide a source of optical illusions to pick the ones more suitable for teaching.

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