TEACHING MATH WITH GEOGEBRA WHILE DEVELOPING A PASSION FOR PHOTOGRAPHY

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Abstract

While teaching math by using photography with interactive software, many important connections are made by the *GeoGebra* tools. Students are often motivated and excited by photography. This paper will show how mathematics teachers can insert photos into *GeoGebra* Software and then explore the math relevance in the photograph, i.e. shapes, symmetry, measurement, fractions, parabolas, etc. By using software and a multi-discipline approach, many of the Common Core and State Math Standards are covered while also helping students develop a passion for photography. *GeoGebra* is a free software and can be download in a variety of formats or used online, today most schools K-12 are embracing this technology in their classrooms as a dominant tool for teaching and linking geometry, measurement, algebra, etc. The authors hope to teach math with relevance using the technology and photography and aiding students to develop a passion for photography.

Keywords: Teaching Mathematics, GeoGebra, Photography, Technology, Standards, Passion

Presented virtually for the 32nd International Conference on Technology in Collegiate Mathematics (ICTCM), Orlando, Florida, accepted for Friday, March 13, 2020.

Introduction

"Of all of our inventions for mass communication, pictures still speak the most universally understood language."

-Walt Disney Company

Today it is critical to make important connections while showing students math in the real world. Students are often motivated and excited by photography. This session will show how mathematics teachers can insert photos into *GeoGebra* Software and then explore relevant concepts in the photograph, i.e. shapes, symmetry, measurement, fractions, parabolas, etc. By using software and a multi-discipline approach, many of the Common Core Math Standards are met while also helping students develop a passion for photography.

From the perspective of the authors who both have a passion for photograph, this paper will promote a passion for math learners by using the software *GeoGebra* and develop a passion for photography. The authors advocate using emerging technologies like *GeoGebra* by inserting photos into *GeoGebra* and relating the math ideas in the photos. Students see an appreciation for math around us and in everyday life (Gorriz & Vilches, 2019). When using visuals, students are often highly motivated by using photos that appeal to their senses while exploring the mathematics within them. Antje, Hannula, & Toivanen (2018) found that when using outdoor photography for teaching math that it had a positive impression on students and their learning of mathematics.

When we teach mathematics, connections need to be made (Zengin, 2019). Munakata and Vaidya (2012) based on their research found that students do not consider mathematics and science to be creative endeavors, although the traditional artistic disciplines rank high in this regard. The authors addressed the problem in perception by using photography to embolden students to find the inherent link between science and math and the arts. The photography project was implemented in a prescribed classroom environment as well as an outdoor exploratory activity, i.e. in a more informal setting, or the real world. When photography was part of the instructional strategies to teach new material, the project found student interest and motivation were peaked by making meaningful connections to the math using the photography. Jones (2012) in her book, *Visualizing Mathematics*, discusses how teachers need to help students visualize and create representations of their math understanding to become enthusiastic about the subject.

By using technology and photographs, our young learners are excited to construct and investigate mathematical ideas. The presenters encourage students to see and appreciate the world around them and maybe inspire them into the STEM fields that are so critical

today. Abraham (2019) contends that when someone has a passion for something like photography, they can help to share their love with others to develop a passion. Professor of Mathematics, Dr. Marinas, will share how her passion for photography led this research and presentation. Dr. Marinas will offer some tips on photography and share some prized photos.

GeoGebra

Although the study of geometry has been in existence for various millennia, it is within the past twenty-five years that a shift has occurred in how geometry may be learned through computer-based interactive geometric software like *GeoGebra*. Technology like *GeoGebra* allow users to construct interactive illustrations of points, lines, shapes, and circles. These geometric ideas are dynamic and interactive in that they may be resized and shifted around onscreen through clicking and dragging actions. Additionally, interactive geometric software like *GeoGebra* in the K-12 mathematics core curriculum has been used at the elementary level, middle school level, and the high school level (Yu & Tawfeeq, 2011) and has confirmed that using software like *GeoGebra* is a very positive resource for teaching and learning math.

Whereas Fahlberg-Stojanovska, & Stojanovski (2009) observed students as they made conjectures as they draw and measure onscreen, they discovered that using *GeoGebra* technology was useful to stimulate and help young people learn math at higher levels. Rosen & Hoffman (2009) found that it is very important to assimilate both concrete and virtual manipulatives into the primary-age math classroom, which then gets them ready for the representational models on the computer technology like *GeoGebra*. When first using geoboards and the software like *Paint*, Furner & Marinas (2015) found that children easily transition to the abstract with the sketching software *GeoGebra*.

GeoGebra is a great source and high-tech means that when used in the math schoolroom provides a focus to:

- encourage technology as an essential tool for teaching mathematics in the 21st century
- assimilate the principles and process standards with learning the content standards
- affords access to all mathematics standards for all learners
- supports learner-centered approaches that address the diverse needs of all learners of mathematics

GeoGebra permits students to actively build their own understanding of many math concepts like: geometry, measurement, and algebra using this software. Using *GeoGebra* math teachers can meet the Common Core Math State Standards (CCSS), students can master many math concepts such as:

- employ the polygon and circle apparatuses to draw shapes
- measure angles area, and lengths
- activate *GeoGebra* sliders to adjust values for different math problems

- use the insertion of images into the software to demonstrate mathematical problem solving and real world ideas
- distinguish perimeter as a characteristic of plane figures and differentiate between linear and area measures, etc.
- discriminate between shapes and their attributes

Effective math educators can make the most of the potential of *GeoGebra* to:

- advance students' understanding
- arouse their curiosity
- upturn their aptitude in mathematics

GeoGebra is a free technology, a multi-platform dynamic math and geometry software for all echelons of education that links geometry, algebra, tables, graphing, statistics and calculus in one easy-to-use compendium (Hohenwarter, Hohenwarter, & Lavicza, 2009). *GeoGebra* has a huge international consumer and designer community with users from 190 countries. The technology is presently translated into 55 languages and demands close to 300,000 downloads per month. *GeoGebra* may be downloaded free and/or accessed at: http://www.geogebra.org.

Making Connections when Teaching Mathematics

Today it is important that educators make important connections between the school curriculum and the real-world to better reach learners. Connections need to be made when we teach mathematics per Zengin (2019). Connections between the Common Core State Standards and the National Council of Teachers of Mathematics (NCTM, 1989, 2000) Standards need to meet the challenges of differentiating mathematics instruction in the K-12 classroom. Research from Small (2012) expounds two powerful and widespread strategies that teachers can use across all math content: Open Questions and Parallel Tasks. Presenting teachers on how to start and become experts with these connection approaches, Small (2012) demonstrates more inclusive learning conversations that promote broader student participation and mathematical thinking. Direction for creating a more inclusive classroom learning environment with mathematical exchange that engages learners is important (Small, 2012). While using common math technology and covering the compulsory math standards by making connections for sound learning, students can work together and use the technology like *GeoGebra* to involve in higher level mathematical thinking.

With the Common Core Standards (National Governors Association Center for Best Practices - NGA Center, 2010) in teaching mathematics, teachers need training to learn new mathematics content and technology to become effective in reaching their students (Andresen & Misfeldt, 2010). An understanding of software like *GeoGebra* cannot be insulated from the content and good math instruction which necessitates an understanding on how emerging technologies are related to the pedagogics and math (Hughes, 2005).

Today, most schools and states are adhering to the Common Core Math Standards (National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO), 2010) found at: http://www.corestandards.org/. A sampling of objectives from the Common Core Standards that can be addressed using the *GeoGebra* software and noted in many photos and examples below are as follows:

Covering the Common Core Math Standards: Connecting Math and Photography

CCSS.MATH.CONTENT.K.G.A.2
Students can correctly name shapes regardless of their orientations or overall size.

CCSS.MATH.CONTENT.2.G.A.1
Recognize and draw shapes having specified attributes, such as a given number of angles or a given number of equal faces.1 Identify triangles, quadrilaterals, pentagons, hexagons, and cubes.

CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.

CCSS.MATH.CONTENT.6.G.A.3
Draw polygons in the coordinate plane given coordinates for the vertices; use coordinates to find the length of a side joining points with the same first coordinate or the same second coordinate. Apply these techniques in the context of solving real-world and mathematical problems.

CCSS.MATH.CONTENT.8.G.B.7
Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.

CCSS.MATH.CONTENT.HSG.CO.A.1
Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc.

Using Photography to Teach Mathematics

Math teachers may want to do two-minute math starters problems like the following using photos to start and motivate a class lesson:

Can you identify where each one of these photos was taken [See Figure 1]? Do you see any mathematical ideas in the subsequent photo?

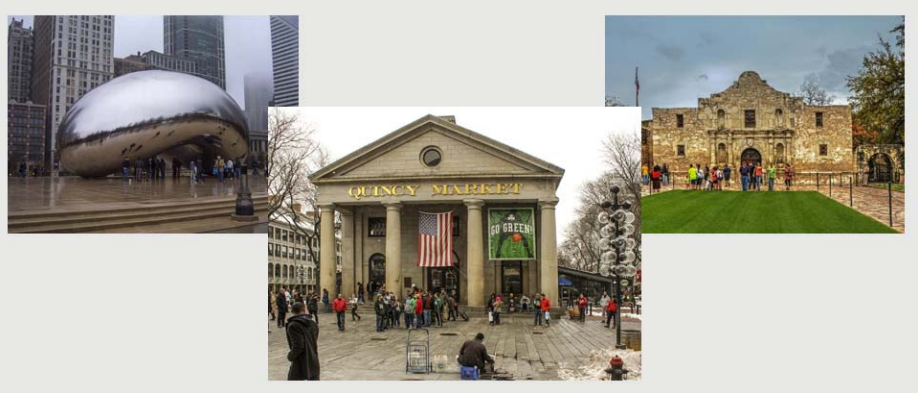

Figure 1. Identify the Photo Locations and Mathematics in them (© Carol A. Marinas)

Munakata and Vaidya (2012) found in their research that young learners do not consider math and science to be creative undertakings, although the typical artistic fields rank high in this regard. To tackle this problem, the authors used photography to embolden students to find inherent connections between science, math, and the arts. Their photography assignment was implemented in a formal learning classroom environment as well as an external activity, i.e. in a more informal setting in the real world. They found that when photography was part of the instructional approaches to teach new material, meaningful connections were made between mathematics and photography. Bragg & Nicol (2011) contend that students can have success with learning math when they use photos and problem solving together. Relating and understanding real-world problems by using interactive technology and photography makes important contacts in mathematics.

By using photography, *GeoGebra*, and students working together to learn math, students were more motivated to learn the math concepts and the photography as it relates to the real-world (Rizzo, del Río, Manceñido, Lavicza, & Houghton, 2019). Through their research and analysis, they found using a combination of three approaches helped to engage learners by relating photography/art, students' surroundings/real-world, and the mathematics content proved to enhance instruction and success with the subject. When educators support learning like using photography and the visual arts in teaching math, it enhances the learning and success for understanding mathematics and photography in the topics of ratio, shapes, and other mathematical and shared ideas (Portaankorva-Koivisto & Havinga, 2019).

In 4th grade, Dr. Marinas, began her love of mathematics with plans to share this knowledge through education. By 6th grade, photography became a part of her life by taking images on school field trips, vacations, and family gatherings including weddings. She concentrated on math during high school and college in mathematics education. During her pursuit of her Master's Degree, she developed 35 mm film in her own black-and-white

darkroom. After completing her Ph.D., she dedicated more time to photography using her digital camera. Since then, she has won many photography competitions as well as participating in five gallery showings.

It is important that we develop a passion for photography in our students for those who are interested. Abraham (2019) contends that when someone loves like they do or have a passion for something like photography, they can share their love with others to develop their own passion. In this paper, Dr. Marinas, Professor of Mathematics, shares how her passion for photography led to this research and presentation. Antje, Hannula, & Toivanen (2018) found that when using outdoor photography to teach math, it had a positive impression on students and their learning of mathematics. We need to encourage our learners to recognize that geometry and shapes/mathematics that surround us! More math can be learned using photographs to teach mathematics. Spring (2020) contends that educators can teach math, English, physics and other subjects using photography. In her article, Oswald (2008) reported teachers can use photography to teach and learn science, math, and writing. Jaqua (2017) contends using photos and even selfies have benefits for students in learning mathematics. By encouraging students to see the math as they take photos as well as value the world around them, math can then be more meaningful for learners. Encouraging students to take photos may help them develop a passion for photography and help develop a long-term creative outlet and passion for life. Mathematics lends itself well to incorporating photography into its discipline.

Math teachers can ask their students what math concepts can you see in the photo below [See Figure 2]?

Figure 2. Identify Math Concepts in Photo in Orlando (© Joseph M. Furner)

Photography Tips for taking Great Photos

When a math teacher is using photography by inserting photos into *GeoGebra*, they can share many tips for taking photos and encourage a passion for photography. Spring (2020) offers many photographer instructions for how to take photos and how to incorporate

mathematics ideas as it relates to photography like looking at shutter speed and aperture creating many types of math problems. One classroom-based venture using photography to teach with, a head teacher, Liz Becks, fashioned a project to learn science, math, and writing employing photographs. Becks is cited in an article saying "There's something in nearly every subject that relates to photography, and it's a topic that appeals to kids" (Oswald, 2008, p. 1). By using photography within instruction, educators are appealing to learners and creating a passion for photography. Photographers often know a lot about their hobby or profession, about lighting, speed, objects, backgrounds, etc. in order to take great photos. Dr. Marinas has prepared the below tips for taking photos as they relate to mathematics.

Photography Tips: Rule of Thirds

Figure 3. Rule of Thirds (© Carol A. Marinas)

The "rule of thirds" in photography is created by adding two horizontal lines and two vertical lines. The goal is to have your main subjects at the intersections as noticed in Figure 3. According to a photography website: http://photosbypassy.com/?p=742, "Doing this adds balance and interest to the picture."

Photography Tips: Parallel Lines

Figure 4. Parallel Lines (© Carol A. Marinas)

Taking photos with parallel lines provides depth and a three-dimensional illusion to a picture. To create depth to a photo or a sense of infinite space, it is good to incorporate parallel lines in pictures including columns, steps, crops, railroad tracks, and other things that create repeating diagonal or converging lines together. According to: http://photosbypassy.com/?p=742, parallel lines in a photo [See Figure 4] can also take viewers a on journey as stated, "This gives the picture a three-dimensional story to it, and makes us go on a "Journey" through the scene."

Photography Tips: Perpendicular Lines

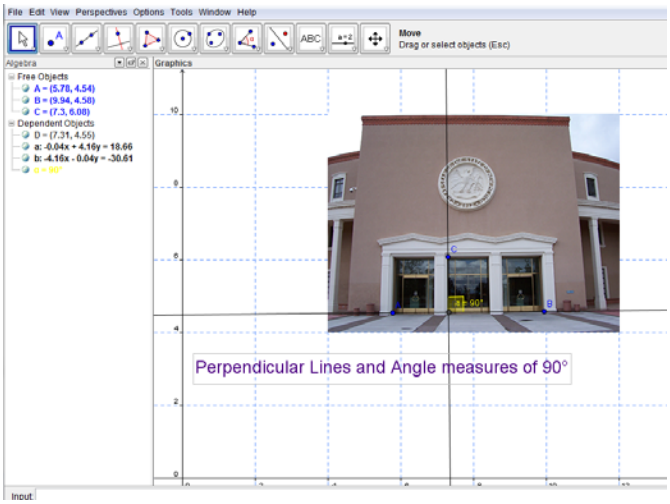

Figure 5. *GeoGebra* file showing Photo of Perpendicular Lines (© Carol A. Marinas)

Perpendicular lines create right angles, 90 degree angles, and like in the *GeoGebra* file photo above [See Figure 5] form right angles and perpendicular lines as confirmed with the *GeoGebra* software. "The L-shape design is the a very commonly used structure in landscape paintings, where it creates a sense of peace and serenity" as cited on: http://www.explore-drawing-and-painting.com/art-composition.html.

Photography Tips: Circles

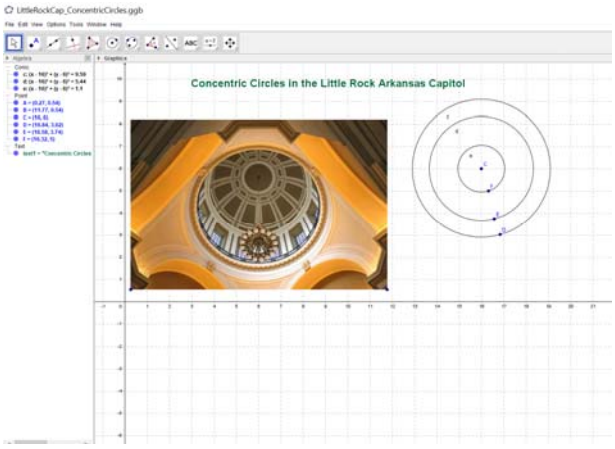

Figure 6. Circles and Concentric Circles in *GeoGebra* (© Carol A. Marinas)

Expert photographers as cited on: https://expertphotography.com/line-shape-and-form-photography-composition, believe that: "Rounded shapes, like circles and ovals, create a sense of movement because of the lack of corners and edges." The photo in Figure 6 was inserted into *GeoGebra* and then students were asked to draw circles and concentric circles in the dome of Little Rock Capitol building). When a photographer uses circles in photos, "You can capture a certain energy with the motion of a circular line, and lead your eye through the frame" as cited on https://digital-photography-school.com/advanced-composition-using-georgraphy/.

Photography Tips: Parabolas

Figure 7. Parabolas (© Carol A. Marinas)

Parabolas often act as a frame around the central object per Dr. Marinas and can be seen in Figure 7 above with the examples of photos of parabolas taken.

Photography Tip: Similar Shapes

Figure 8. Similar Shape Photos (© Carol A. Marinas)

Similar shapes "appeal to the viewer's sense of order, and can make for very interesting images" as cited on: https://digital-photography-school.com/6-advanced-composition-techniques-to-improve-your-photos/. Figure 8 depicts two photos with similar shapes, one with a repeating pattern of hexagon shapes in a bed quilt and the other with birds in a tree.

Photography Tips: Reflections

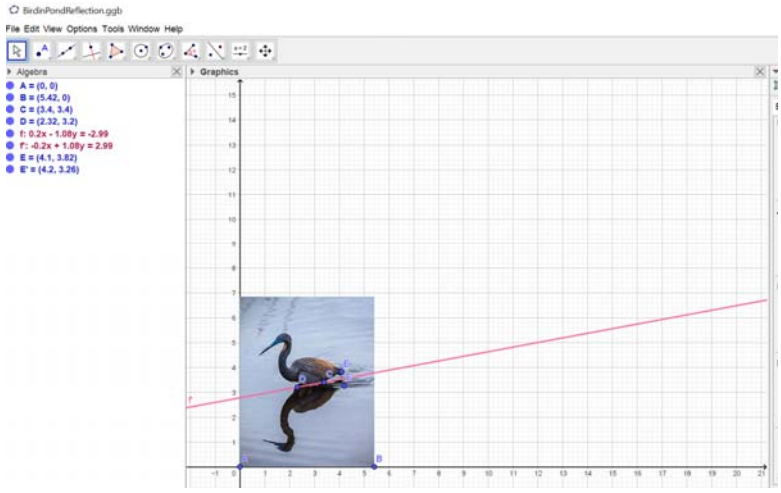

Figure 9. *GeoGebra* File Showing Photo and Line of Reflection (© Carol A. Marinas)

Reflections can appear when one takes photos of water, glass, or any other type of reflective superficial. In Figure 9 it shows a photo of a reflection of a bird in water with a line of reflection draw using *GeoGebra*. "Using water, windows, mirrors or any sort of reflective surface can change an image into a work of art. The wonderful thing about

using reflections when taking photos is that they can completely alter the image from something fairly straightforward to something richer or abstract or otherwise more artistic" as cited on: https://www.smashingmagazine.com/2008/11/50-beautiful-examples-of-reflections-photography/.

Photography Tips: Symmetry

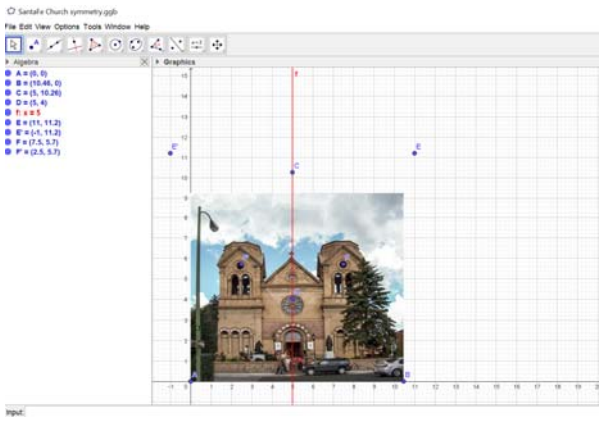

Figure 10. *GeoGebra* File of Symmetry of Photo of a Church (© Carol A. Marinas)

Figure 10 shows a photo inserted into the *GeoGebra* software, a line and point was drawn and reflected along the line to show the symmetry to each other. "Symmetry lies at the heart of the laws of nature. It is calming and pleasant to the eye when an image features a symmetrical composition" as cited on: https://passionpassport.com/spice-up-your-photography-with-geometry/.

Photography Tips: Tessellations

Figure 11. Photos of Tessellations, a Floor and Bedspread (© Carol A. Marinas)

Tessellating patterns are repeated patterns with the same fundamental region covering a space like seen in the floor tile or the bedspread design in Figure 11. Photos that include patterns or even tessellations are visually captivating as it proposes congruence and tempo in the picture. The harmony and rhythm of the picture can make the observer feel a sense of peace and order. Photographers believe when they take photos of "Repeating geometric patterns is especially effective because it creates a bold statement" as cited on: https://expertphotography.com/geometric-photography/.

Albert Einstein had an affinity for both mathematics and photography, he is noted for the following mathematics and photography quotes:

> *"Do not worry about your difficulties in Mathematics. I can assure you mine are still greater."*
>
> *"A photograph never grows old. You and I change, people change all through the months and years but a photograph always remains the same. How nice to look at a photograph of mother or father taken many years ago. You see them as you remember them. But as people live on, they change completely. That is why I think a photograph can be kind."* [All individual quotes used in this paper were found on: https://www.goodreads.com/quotes]

Summary

"Every child is an artist. The problem is how to remain an artist once he grows up."

-Pablo Picasso

Young people intrigued by technology will construct and investigate geometric shapes and many math ideas with *GeoGebra* and will start enjoying math and see connections between mathematics and photography. It is important to make such connections when teaching math using *GeoGebra* and photography because they:

- show a purpose for math in life
- make connections and relationships between math and photography while covering important math concepts
- use emerging technologies in math with applications for the real world
- demonstrate practical uses to math in daily life
- employ innovative teaching in the classroom
- stimulate excitement through Photography/Modeling
- help students develop a passion for photography in the process of learning math

In a globally competitive world where it is more important to prepare our students for science, technology, engineering, and mathematics (STEM) fields, using *GeoGebra* software covers all the STEM areas. It applies math, science, and engineering ideas while using and applying the technology of *GeoGebra*. When using digital photography to teach math, young people are motivated to develop a passion toward photography. What better way to learn math than to use photos and to see the math within them by applying the *GeoGebra* math tools? Pictures still speak the most universal language; a picture is worth a thousand words as they say and photographs can be so inspiring and kind! Our young people can become artists with their photography and use the technology to understand the mathematics they need to learn! When our young people grow up, they can remain artists with a passion for photography!

PowerPoint and Data Files for *GeoGebra* as they relate to this presentation and paper can be accessed at: http://matharoundus.com. See Appendices A and B for additional resources and examples for using GeoGebra and Photography.

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Appendix A: GeoGebra and Resources for the Classroom

Web Sites	**URL**
Common Core Math Standards	http://www.corestandards.org/
GeoGebra Website	http://geogebra.org
GeoGebra Data Files	http://matharoundus.com
GeoGebra Wiki Forum	https://wiki.geogebra.org/en/Tutorials
National Council of Teachers of Mathematics	http://www.nctm.org
GeoGebra Teacher Resources/Materials	https://www.geogebra.org/materials?lang=en
National Library of Virtual Manipulatives	http://nlvm.usu.edu/en/nav/topic_t_3.html

Appendix B: Photography Tips

Web Sites	URL
Digital Photography School: 6 Advanced Composition Techniques	https://digital-photography-school.com/6-advanced-composition-techniques-to-improve-your-photos/
Digital Photography School: Advanced Composition using Geometry	https://digital-photography-school.com/advanced-composition-using-georgraphy/
Expert Photography: Geometric Photography	https://expertphotography.com/geometric-photography/
Expert Photography: Line, Shape, and Form Photography Composition	https://expertphotography.com/line-shape-and-form-photography-composition
Explore Drawing and Painting: Art Composition	http://www.explore-drawing-and-painting.com/art-composition.html
Passion Passport: Spice Up your Photography with Geometry	https://passionpassport.com/spice-up-your-photography-with-geometry/
Photos by Passy	http://photosbypassy.com/?p=742
Smashing Magazine: 50 Beautiful Examples of Reflections Photography	https://www.smashingmagazine.com/2008/11/50-beautiful-examples-of-reflections-photography/

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In 4th grade, Dr. Marinas began her love of mathematics with plans to share this knowledge through education. By 6th grade, photography became a part of her life by taking images on school field trips, vacations, and family gatherings including weddings. She concentrated on math during high school and college in mathematics education. During her pursuit of her Master's Degree in Mathematics, she developed 35 mm film in her own black-and-white darkroom. After completing her Ph.D. in Mathematics Education, she dedicated more time to photography using her digital camera. Since then, she has won many photography competitions as well as participating in five gallery showings.