

Shedding light on art; the use of optics in visual art

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In the world of art, nothing is original. Artists are well known for stealing, borrowing, exploiting, commentating, mocking, and cheating. These behaviors come about as artists strive to create their best work in each of their creations. The artists that makeup history were some of the most creative individuals to walk this earth, but not all of their amazing works were created from skill alone. Looking into art history and the modern practice of art restoration and conservation, my students and I will investigate how the contemporary world uses optics and optical techniques to learn about the past.

Background

Christiana High School is located in the Christiana section of Newark Delaware and serves a population of about 1,000 students. At Christiana, or as we call it, CHS, we support and educate a very diverse community of students. Our students range from high school students to Middle School Honors Academy students to Dually enrolled High School students who also take classes at Wilmington University, to the REACH program (a special education program). All of CHS's students come to us with their individual interests, goals, and challenges, making the campus a hive of diversity and learning. Working within our Title-1 district of Christina School District, about 34% of Christiana's students are classified as low-income, also known as low socioeconomic status or SES for short.

Not to be deterred by their precipitating factors, my students overcome challenges on a daily basis to achieve their goals. I primarily work in the Middle School Honors Academy, teaching students in grades six through eight. I came to this position after five years of teaching elementary school. I have the unique opportunity to level-up with my students as they transitioned from elementary to middle school. This unique situation has allowed me to with a portion of my student population for seven years. Currently, my sixth and seventh-grade classes are in my room for a marking period, while my eight grade has art for or an entire semester. All of the students of the Middle School Honors Academy or MSHA have been accepted to this choice only school through a process of applications, tests, recommendations, and selection. Being a choice only school means that none of our students would regularly attend MSHA based on their geographic location. All of our students would typically participate in one of the three other middle schools in the district but have chosen (and been accepted) to attend the MSHA. The culture of my school is one of big goals and high achievement. My students are naturally determined to learn and question the world around them. While their desire to learn is a

teacher's dream, my middle school students are still in the grips of adolescents. My young learners impress me on a daily basis with their insight, thinking, and talent.

I have designed my classes to focus on student critical and creative thinking. In each of my classes, I employ the choice model of art education. In this style of a classroom, students are designing their own artistic problems to solve. I challenge my students with focus topics or ideas, teach them about artists or the history behind these ideas, then set them free to make art that answers the common theme. This practice allows me to get to know my students as people and artists quickly.

Rationale

My students are inquisitive and curious individuals; they naturally seek out the timeless question; why? My students investigate and analyze everything they experience. They make an effort to better understand the world around them, learn from it, and then change it. This boundless inquiry needs to be met with rigorous and interesting content. My students deserve to experience art and education at its deepest level. Through a deeper understanding of the electromagnetic spectrum and its use in the world of art, I am better equipped to quench the thirst for knowledge of my students. My investigation into the science behind light, color, optics, and sight will spill into my classroom through all my curriculum. As an artist, my students manipulate the work around them to create. Bringing in a deeper understanding of optics will bridge art and science; connect lessons and ideas my students have learned or will learn outside of my classroom.

Additionally, the state of Delaware recently adopted the National Art Standards. Through this adoption, I am now tasked with teaching more than just artmaking. These new standards highlight all aspects of the artistic process as well as historical and cultural practices. The display and maintenance of artworks throughout history is now a part of our new standards. I am driven to work with my students to create opportunities for them to investigate different historical and cultural practices when it comes to the presentation of artworks.

Light

Light, as we experience it on a day to day basis, is only a fragment of the whole picture. Light ranges from gamma rays to radio waves and is non-visible at either end. Light is part of what is known as the electromagnetic spectrum. The part of the spectrum that we are able to see as humans is known as the visible spectrum. This spectrum ranges from red light to violet light, with all the color in between. The image below is a representation of the spectrum of light; in it, we see that the visible spectrum is only a small portion of the whole. In my opinion, the best way to comprehend the vastness of the spectrum through a visual. An internet search of the Electromagnetic spectrum will result in hundreds of charts, graphs, and depictions of the spectrum.

Rays Waves and Particles

When light is emitted from a source, it travels outward from that source, which is where the term ray comes from. In reality, these rays of light are actually waves. Light travels through space as an oscillating wave with peaks and valleys. Scientifically, the peaks are called crests, and the valleys, troughs. The distance between two crests or troughs is known as the wavelength. The size of the wavelength dictates what type of light is produced. Each type of light has different wavelengths; for example, radio waves have a very long wavelength, while gamma rays and ultraviolet light have shorter wavelengths. These different lengths of waves give each type of light its properties, color, and abilities. The height of the wave, measured from the tip of the crest to the bottom of the trough, this measurement is called the amplitude. The amplitude of the light wave correlates to the intensity or brightness. The greater the amplitude of the wave, the brighter or more powerful the light. All types of light can have a high or low amplitude. Another key component of the light wave is its frequency. Frequency is the number of oscillations that move past a point in a given time period. Frequency is measured using hertz and is specific to each light type. For example, red light is around 430 trillion hertz, while violet light is 750 trillion hertz.¹

Light can also be looked at as particles. Photons are tiny packets of energy that we experience as light. To our best understanding, light is both a wave and a particle. A photon is created as electrons move from a higher energy level to a lower energy level in the atomic makeup of the source. For example, the sun is approximately 74% hydrogen and 24% helium; as the electrons in the helium and hydrogen atoms move, they give off photons. These photons travel from the sun to earth, consisting of the entire electromagnetic spectrum.

White Light and Color

White light is the combination of all colors in the visible spectrum. When we see a white object, the object is reflecting all light back at us. The opposite is true of black objects. The color black actually absorbs all light that is shone on it, reflecting nothing. Color, as we experience, is part of what we call the visible spectrum. This spectrum, as illustrated above, is only a small fraction of the entire spectrum. When we see color on an object, such as a flower, it is, in fact, a reflection of that specific light wave or combination of waves.

Visible versus Non-Visible

While light sources like the sun emit all of the electromagnetic spectra, the human eye can only process a small portion of the waves. Modern conservationists have an army of filters, cameras, scopes and digital imaging tools to investigate

Optics in Art

Throughout history, artists have used tools, tricks, and techniques to represent the world around them. Early artists of the ancient world use their first-hand experience and observation to create images. Beginning with seeing a reflection in the water, humans have observed the way light interacts with the world for thousands of years. As technology advanced through history, artists of the renaissance period began to utilize optical devices in their work.

Multispectral Imaging

The art historians and restorationists of today are armed with an arsenal of technology for the analysis of historical and ancient paintings; several of these tools are based in the world of optics. The use of multispectral imaging is being used to analyze underpaintings and sketched beneath some of the world's most famous masterpieces. An underpainting is a preliminary painting done by the artist to begin their masterpiece — a common technique where artists map out darks, lights, and neutrals; getting a look at the underpainting exposes more of the history and story of a painting. For example, Van Gogh often painted on canvases over and over.

Vincent Van Gogh's life as an artist is comprised of many ups and downs. At one point in his career, Van Gogh was institutionalized in a mental hospital. During this time, his art supplies were limited to what his brother could afford and deliver to him. Before his time in the institution, life as an artist was often challenging and short on funding. Driven by the need to create, Van Gogh often painted over his abandoned paintings to reuse the canvases. Today through the use of multispectral imaging and the use of x-rays, a group of scientists have created a way to see into and underneath layers of paint. The team used Synchrotron Radiation Based X-ray Fluorescence Elemental Mapping² to bring out an image of a woman's face from Van Gogh's Patch of Grass 1887.³ This imaging process is possible through the use of the non-visual spectrum of light.

Types of Light Used

X-Rays

We are all familiar with the term x-ray, and anyone who has ever broken a bone or been to the dentist knows that x-rays have the ability to see through things, but how does this work? German physicist Wilhelm Röntgen is credited with first discovering x-rays in 1895. A discovery by accident, Röntgen was experimenting with electronic beams passing through tubes of gas.⁴ X-rays have very short wavelengths. This property allows them to penetrate materials and surfaces. In x-rays of our bodies, the calcium in our bones interferes with the waves of x-rays, absorbing much of the x-rays, thus producing

an image.⁵ In paintings, x-rays react with the different pigments in different ways, occasionally creating false colors. Through an understanding of pigment's reaction to x-rays, art historians can guess the original color of a pigment-based off the false-color illustrated under x-ray light.⁶

Infrared

Another type of light used in art restoration and history is infrared. Infrared light falls just outside the visible spectrum toward the red side. You may have heard of infrared light used for heating purposes, but not all infrared is used to create heat.⁷ Infrared can be used in a non-destructive way to examine paintings by illuminating hidden parts of the painting, such as signatures, watermarks, or added material.⁸ This occurs because each material and pigment in a painting has its own infrared fingerprint.⁹ Similar to Ultraviolet light and x-rays, infrared light reflects off materials in specific ways. Through studying infrared light in other situations, a modern scientist can form guesses about the material composition of the painting.

Ultraviolet

Ultraviolet or UV light is used to examine paintings. We have all experienced UV light as black lights, and its ability to make certain material glow or illuminate. Art restorationist uses ultraviolet light to examine paintings for retouching or edits.¹⁰ They shine UV light on a painting to make the different pigments, fillers, and varnishes luminesce. Sometimes known as “UV-induced fluorescence”¹¹ This technique illuminates different materials and substances on or in a painting. This is essential information for restoring a painting, and it lets the restorationist know where the original work stops and where retouching begins. Armed with this new knowledge, historians can make essential decisions, and edits can be made to remove the material or add material.

To capture the materials illuminated under UV light, an art conservationist will use a full spectrum (standard) digital camera; but may employ the use of an older style lens. Modern camera lenses have antiglare coatings that filter out some of the light spectra.¹²

Application of Multispectral Imaging

To get an intimate view of a painting, scientists, art historians, and art restorers are using the parts of the non-visible spectrum of light. A simple internet search for the use of multispectral imaging in art restoration or conservation will result in several examples and visual deconstructions of the process. The process of multispectral imaging uses different wavelengths of light to see through and underneath the pigment on in a painting. The technique allows art historians and restorationists to have x-ray vision, although x-rays are not the only wavelength used. Under visible light, we see the painting as it naturally appears to us. The surface is absorbing and reflecting color back at us at

different rates depending on which section of the electromagnetic spectrum is shown on it.

The technique of multispectral imaging was first used in the early nineties and is still used today due to its noninvasive properties.¹³ In its early life, multispectral imaging consisted of shining filtered light on an object, primarily painting, then looking at this light through a monochromatic digital camera.¹⁴ A monochromatic digital camera is a device that only receives/interprets light of a specific color. The term monochromatic is defined as of one color, consisting of the prefix mono, meaning one, and chroma meaning color. In digital cameras, a sensor replaces the film of traditional cameras. Modern technology allows us to control the sensitivity of the sensors to accept all or specific colors. Due to the specialized nature of sensors in digital cameras, we can capture a specific wavelength of light.

Pigments

Pigments function much differently than light. In pigments, we are dealing with the reflected outcome; it is a subtractive process while the light is an additive process. Mixing pigment is subtractive because while we are adding two or more colors together to make a new one, the less light of the electromagnetic spectrum is reflected.

Decay

Every art conservationist demise is the decay of materials. Wooden frames rot, canvases disintegrate, and colors fade. All of the element's artworks get exposed to take their toll on the work. Light can be just as damaging as humidity or heat. Pigments react to light over time, as light waves can cause a chemical change. Light interacts chemically with pigments in paints and other materials. This occurrence is called photodegradation.¹⁵ The chemical process of photodegradation occurs when photon infiltrates pigments in the artwork and work their way into the chromophores. A chromophore is a light-absorbing material inside pigments and dyes. Made up of a group of atoms, these chromophores are responsible for giving objects their color.¹⁶

The technical term for color fading is photodegradation.¹⁷ There are light-absorbing color bodies called chromophores that are present in dyes. The colors we see are based upon these chemical bonds and the amount of light that is absorbed in a particular wavelength.¹⁸ The National Gallery explains the effect of light on artwork as a "photochemical action."¹⁹ Or a "chemical change at the molecular level and is the more profound transformation resulting from exposure to light. The most potent sources of these destructive energies come from just beyond the limits of visible light—ultraviolet (UV) and infrared (IR) light."²⁰

Strategies

Collaboration

Art class is natively an environment where collaboration takes place. In this unit, students will work collaboratively to form hypotheses, experiments, and presentations. I use collaboration in my teaching to engage my students as active learners. Middle school students are some of the most socially driven individuals I have ever worked with. They jump at the opportunity to work in partners or groups. This natural motivation to work together is embraced through the use of collaborative learning.

Peer Teaching

I truly believe in the power of students teaching students. To accomplish this task, I utilize peer teaching in many of my day to day lessons. In this unit, students will use peer teaching techniques such as pair-share and presentations. Peer teaching is used to create a level of community and comfort within the classroom. It empowers students to take on a leadership role amongst their peers. In my art room, my students are well accustomed to speaking to the class. We spend a lot of time having open, class-wide discussions and conversations.

Occasionally students are uncomfortable in front of the group. To combat this, I keep my peer teaching time concise and give students the option of teaching from their seats, in front of the class, making a video, or creating a reading. All of these are practiced methods of teaching, with each having its own individual benefits. The creation of an informational video is by far the greatest undertaking, but it allows learners to return to the content as they need or progress through it at a pace most comfortable to them. The students who elect to make an informational video are often intrinsically motivated and accustomed to editing video.

Investigative research and fact-checks

A major part of being a student in the twenty-first century is knowing how to utilize the resources available. Many of my students are still unsure of how to conduct valid online research. In many cases landing on public sites, such as Wikipedia, students accept the first thing they read as the truth. Investigative research will be used throughout this unit to accompany class experiments and discoveries. Students will utilize online resources like UDlibsearch, online journals, and trusted website will be used. To ensure students are using trustworthy information and sites, each student will fact-check each of their sources. Each time a student uses a new resource for information, they will be required to fact-check it against another source. This process will take place in the document. A stipple two-column table will keep students organize. The left column will be the fact or new source; the right will be the supporting information or organization.

Online annotation

As students practice their research skills, the online annotation will be used to create and maintain healthy research habits. Students will be introduced to online annotation tools, such as different browser extensions. A simple internet search will provide access to different resources. Students will utilize online annotation to keep their research organized. This strategy will allow students the ability to access their notes and information quickly.

Electronic Participation

The use of different participation and connection methods is tried and true in education. In this unit, students will be introduced to reminded of different electronic ways to participate. As the teacher, I use these methods as formative assessments, allowing me to gauge their learning in real-time. Online reviews and quizzes are readily available for use in classrooms. Armed with their Chromebooks, my students are naturally driven to engage in a lesson via technology. The use of shared online documents allows for multiple students to collaborate on a single piece of writing or work.

In this unit, students will utilize their one-to-one devices to create and collaborate. Shared documents and presentations will be used in many of the activities as students work in partners or teams to investigate light's effect on artwork. Each student or group will be responsible for incorporating at least one form of electronic participation in their presentations.

Activities

Classroom Conservations

In this activity, students will search the classroom for objects that may have or could be affected by light exposure. I will break students into small groups of three or four. Each group will spend a few minutes exploring the classroom. My classroom at Christiana is an interesting space, with many multiple sections and sub rooms. The twenty-foot ceilings and clerestory windows bring in large amounts of light throughout the year. The room is so bright at times that I am not able to use a projector. This flooding of light has left its mark on several items in the room.

Student groups will identify one object to investigate, then take observational notes. These notes will include a sketch of the object and its environment. The team will need to identify the amount of light, the direction of light, and the effects of light overtime on the object. To guide them in their investigation, students may use the following questions:

- Has the object been affected by light?

- Describe the extent of the damage?
- Was the object ever moved?
- Do the objects surroundings exhibit similar effects? Or different?

What type of light is best?

Today there are many options to choose from when it comes to the task of producing light. Museums employ curators and lighting designers to create the most authentic view experience for patrons. These controllers of light manipulate modern technology to not only make historic artworks look their best, but also stand the test of time. Students will investigate the effects of different styles of lighting on their artwork or a classroom object.

Materials Needed

- Incandescent lights
- LED lights
- Fluorescent lights
- Lighting films - various colors
- Cardboard tube or small box
- Aluminum foil
- Artwork or object

Procedure

In groups or teams, students will form hypotheses about the effects of different types of light on the appearance of an object. To start, students should be given some time to explore the lighting options, films, and reflective (foil). Students should observe the color of the light, its warmth or coolness, its softness or harshness. Each group of lighting designers will draft a hypothesis about each type of light and what they think it will do to the appearance of the artwork or object. Next, the group will begin to construct different ways of controlling the light. The classroom will be put on a lighting schedule, giving each team time to design and build their experiments, then the lights will be turned off. Teams will observe their object under the lighting they designed and not the changes or lack of an object. This process will repeat for each of the three light sources. Teams will adapt their lighting to change the appearance of the artwork.

While the above activity focuses on the cosmetic aspect of lighting, it is an important step in consideration of lighting for museums and galleries. After the initial design phase, students will create a simple watercolor painting to test out the long-term effects of their favorite lighting device. Inexpensive watercolor is used because of its lightfastness and ability to fade. Paintings will be made on small six-inch square pieces of drawing paper. Once the painting has dried, teams will set up their artwork under their lighting device. The setups will be left for one week, with the lights staying on twenty-four-seven. It is

important to note the physical temperature of some lights, mainly incandescent. Use caution when proceeding, some lights may cause the paper to burn.

After one-week, teams will reassemble to look at the results of their lighting experiments. They should observe the effects of light exposure on the colors of paint, the paper itself, and the appearance of the overall painting. The expected outcome is for students to discover that LED is the least harmful lighting. LED lighting is becoming more and more common in museums today. Students will finally create a display with a summary statement.

Web Quests and presentations

In this activity, students will take to their Chromebooks to discover ways in which the art world is combatting the effects of light on pigments and artwork. Students will spend two classes exploring different web resources such as: databases, videos, museum pages, the National Gallery website, and more. Through this exploration, students will learn about different techniques used today to stop the negative effects of light on works of art. Students will work in pairs to draft a one-page essay about the topic of their choosing from the list below or others generated by the teacher. Pairs will also create a 2-5-minute presentation to give to the class. This presentation will serve as a peer teaching opportunity. Each team of students will investigate a different aspect of art conservation or light in its respect art. Teams will also generate two to four quiz questions the audience will answer following their presentation.

While students are presenting, the audience will take notes on each presentation. The presentation will first introduce the quiz questions to the audience and a way to focus the audience on the topic. Presenters will discuss their topic, making sure to highlight the answers to the quiz questions. At the end of the presentation, the team will send their slides to the teacher. The teacher will then add the slides to a class slideshow. Quiz questions will be used to gauge the understanding of the audience. At the end of the presentations, groups will share their quizzes via an online form. Audience members will take the quiz immediately after the presentations. Results will be used to assess how well the presentation shared information with students. At the end of the unit, the same questions will be used in an open note test. This test will be part of each student's summative assessment for the unit.

To create and foster valid research habits, students will keep a list of their sources in APA format. To do this, students will utilize online bibliography tools and word processing extensions. This will form a connection between ELA class and art class, illustrating to students the importance of solid research and writing skills. Students will include their bibliographies as the final slides or images in their presentation, as well as the end of their essay.

Appendix One

Delaware Art Standards

VA: Cr1.2.8a Collaboratively shape an artistic investigation of an aspect of the present-day life using a contemporary practice of art and design.

The student will meet this standard as they begin their investigation of light's effect on artwork. Every day students turn lights on and off with little to no thought given to the action. As a curator or art conservationist, students would be consumed with the fact that this simple action could potentially damage a world treasure. As students experiment with the everyday object of light and its effect on art, they will be using design practices and values to create lighting systems.

VA: Cr2.1.8a Demonstrate a willingness to experiment, innovate, and take risks to pursue ideas, forms, and meanings that emerge in the process of artmaking or designing

Students will meet this standard during their experiments. Artists take risks, regularly and historically experimenting with new materials, techniques, subject matters, venues, and more. During this unit, students will test out different artmaking materials and gain an understanding of how light affects them. Students will be challenged to use light to change the look of an artwork, which may, in fact, create new meaning in an artwork.

VA: Cr2.3.8a Select, organize, and design images and words to make visually clear and compelling presentations

This standard is an essential part of being in my art room. Students are challenged to meet this standard in all parts of this unit. During the creation of lighting systems, students will need to think about the aesthetics of the actual systems themselves. Can they imagine them in a formal setting such as a museum? What alteration needs to be made to make them gallery-quality? In the same activity, students will assess the effect of light on the viewing of artwork by asking how the light changes the look of the artwork. Is it visually pleasing? Does a specific light type, angle, or combination make a difference? Finally, students will directly meet this standard again in their peer teaching presentations or their web quest. Presentations will be assessed on how well they are designed, how easy/comfortable it is to look at, and how visually compelling they are in relation to the information at hand.

VA: Re.7.2.8a Compare and contrast contexts and media in which viewers encounter images that influence ideas, emotions, and actions

This standard is addressed during web quests and peer teaching. Students will investigate different locations and platforms of art conservation. Students are asked to think about

how the use of lighting, modern technology, and history is being used to preserve the world's treasures. While learning about the field of art conservation through the lens of optics, students are considering a new context for appreciating art as historical value. In many cases, students have only experienced art class as the active creation of artwork, rather than the appreciation and history of artists before them.

Common Core Standards

CCSS.ELA-LITERACY.WHST.6-8.1.A Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

This ELA standard is addressed in the one-page essay students will draft after completing their web quests. Students will draft a concise essay explaining the topic they chose, introduce information about the topic, and provide supporting evidence.

CCSS.ELA-LITERACY.WHST.6-8.1.E Provide a concluding statement or section that follows from and supports the argument presented.

In the process of creating their one-page essay, students will need to formulate a concise conclusive statement. This statement will also be shared with the class at the end of their presentation just prior to giving the quiz.

CCSS.ELA-LITERACY.WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

This standard is the heart of the web quest research project. To meet this standard students will select a topic from a list or engage in preliminary research to identify a topic of their own choosing. Students will use facts, historical context, and modern use to reinforce ideas in their research. During the process of their web quest, students will be encouraged to keep a running list of questions, then given the opportunity to answer them with supporting research. The exploratory nature of the web quest prompts students' research skills.

CCSS.ELA-LITERACY.WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source, and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Students will use a multitude of sources in their web quest research. The use of the fact-check worksheet will provide students the platform to analyze their source for accuracy and legitimacy. By backing each main source with supporting sources, students are

meeting this research standard. Students will also utilize APA style formatting when citing sources. Browser extensions and word processing platforms will aid students in their research and avoidance of plagiarism.

CCSS.ELA-LITERACY.WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.

In their web quest, students will pull information from several resources to support their hypothesis, findings, and other sources. The use of informational texts in the form of online journals and libraries will allow students to meet this ELA standard.

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Notes

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