Humans and the Environment: How Water Pollution and Littering Affect Health

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Abstract

The biosphere is composed of both biotic and abiotic factors that work systematically to perpetuate the Earth we know. Effectively, all organisms interact with the environment around them, including the human populations and communities from around the world. This unit will analyze the effect that human populations have on the environment in regards to littering and water pollution. This unit will be taught through a worldy lens and require students to analyze how water pollution affects different parts of the world and the contributing factors of littering and water pollution in society. The unit will begin by introducing students to an anchoring phenomenon that drives the students inquiry and engagement in the content. The unit will end with the students' choice to create a tangible campaign or engineering design project targeted at eliminating littering and water pollution in the school and surrounding community.

Keywords:

Water, pollution, environment, littering, health, engineering, waterways, urban, world

Unit Content

Problem Statement:

Currently, there is a “pedagogy of poverty” within many urban schools. Essentially, teachers are not challenging students in ways that help them reach their full potential and see themselves as separate from the students that they teach. (Haberman 81-82) This plays a huge role in the educational experiences of Black students within the United States, in particular in predominantly black communities.. Research illustrates that urban youth are disproportionately below basic in science and science area standardized tests (Barton). Moreover, marginalized groups are underrepresented in STEM (Science, Technology, Engineering and Math) attainment. As such, it is essential to bring phenomenon based learning and critical-reality pedagogy into the lives of the students through science in order to increase the representation of marginalized groups in STEM professions and provide a direct outlet for marginalized groups to attain social justice through the means of STEM. To achieve this necessary advancement, research suggests that educators understand and utilize the overlap between science events and student identity (Barton). This unit will be written through the lens of critical reality pedagogy and grounded in phenomenon based learning in order to target the marginalization of Black students in regards to STEM education and careers.

The content of this unit will target the problem of habitual littering in the school and surrounding community as well as other sources of water pollution in urban environments. Currently, all types of trash litters the ground outside of the school as well as the floors of the classrooms and hallways. I often witness my students casually and habitually tossing trash on the floor and hear comments like, “it’s just paper” or, “the floors are already dirty.” Providing insight to students

about the determining factors of littering and analyzing them alongside a deeper understanding of the effects of littering on the environment and community may motivate behavioral change. Personal behavior is not the most important factor contributing to ambient litter and water pollution. Urban areas experience many systemic issues with trash collection as well as urban runoff that contribute to elevated water pollution. The content of this unit will focus on how people, as organisms, interact with the environment by littering and polluting waterways. In the end, it requires students to design solutions to the problem of littering and water pollution in the school and surrounding community.

Content Objectives:

Pollution results when trash or waste is deposited improperly. This deposition of waste takes many forms from factory waste, chemical run-off, inefficient trash pick up, to a potato chip bag dropped on the ground. However, all human induced pollution and littering plays a negative role in the environment. The content of this unit will focus on the variety of connotations that pollution and littering have and the ways that it negatively affects the environment and health of individuals. It will start by focusing on littering of the waterways through contaminants such as sewer overflow and nonpoint sources of pollution such as water drains. The content focuses on the history of legislation to protect waterways in the country and in Philadelphia and the health effects of water pollution of different kinds. Students will then investigate pollution and littering around the world, as well as, the determining factors of littering behaviors and habits alongside the overarching contributors to water pollution such as trash collection and urban runoff. The unit will wrap up with the students' choice between creating and carrying out an advocacy campaign against littering in the school and surrounding community or engineering a product packaging design for sustainability.

Background Information:

Pollution, Littering and Our Waterways: Introduction and Health Concerns

In order to understand the consequences of pollution in the waterways, it is essential to understand the history of the Philadelphia water system and national legislation protecting water. In 1854, the geographic boundaries of the City of Philadelphia as we know them today were conceived. At this point, Philadelphia consolidated with 29 surrounding municipalities. Three major waterworks systems were provided for the city in addition to the Fairmount Waterworks System at this time. They included waterworks supplying the Northern Liberties and Spring Garden areas, Germantown and Mt. Airy areas and Kensington. Additionally, there were a number of privately owned water works that were eventually purchased by the city.

In 1828, before the geographic consolidation, the first major law that targeted pollution of Philadelphia's waterways, in particular the Schuylkill River was established. The act stated that anyone who "willfully take, lead, conduct, or carry off, or shall knowingly suffer or permit to be taken, led, conducted, or carried off, any offal or any putrid, noxious, or offensive matter, from any dye house, still house, brew house, or tan yard, or from any manufactury whatever, into that part of the river Schuylkill which is between the dam at Flat Rock and the dam at Fair Mount" would be charged with a $50 fine. Although this precaution was put in place, and the city created Fairmount Park in order to deter polluting, the drinking water and the state of the Schuylkill

continued to deteriorate because issues of pollution in places such as Manayunk were not being addressed upstream.

At the start of the Civil War and continuing through 1890, Philadelphia's population doubled and the factory presence grew tremendously as the city pumped out goods. Although the amount of industrial waste entering the Schuylkill was toxic to the health and safety of organisms, human waste was arguably more detrimental causing a health crisis such as typhoid fever. Over the following 20 years, there was great debate about the best form of filtration for Philadelphia's water system. There was originally debate between implementing a filtration system or aqueducts. Then, the city settled on using sand filtration plants to filter the drinking water coming from the Schuylkill. Now, the Philadelphia Water Department uses a 7 step treatment of sewage, including disinfection, sedimentation and filtration, before it enters the citizens' supply of drinking water (*Philadelphia Water Department Water and Drainage History Course)*.

Although legislation was taking place at the state level in the 1900s, the national legislation targeting the pollution of waterways didn't come into effect until the twentieth century through the National Environmental Policy Act. This act, signed into effect by Richard Nixon, led to the promulgation of five different Acts that targeted different factors of environmental harm. Among these were the Clean Water Act of 1972 and the Safe Drinking Water Act of 1974. Together, the Acts enforce minimum standards for safe drinking water sourcing and regulate pollution of waterways nationwide. This history of water pollution legislation and strategies for controlling littering and restricting pollution of our waterways with waste and toxic substances eliminated unregulated industrial pollution nationwide. However, littering and polluting of our waterways, especially in Philadelphia is a persistent and growing problem (Environmental Protection Agency).

Two of the greatest challenges to clean water are combined sewer overflows and nonpoint sources of pollution, which are not regulated under the Clean Water Act. In urban areas such as Philadelphia, nonpoint sources of pollution are of particular concern for the waterways Additionally, Philadelphia has 164 combined sewer outfalls along its waterways that deposit bacteria and human waste into the river when big storms occur (*CSOcast beta)*.

Research and data shows that when there is an influx of precipitation, happening more frequently because of the changing climate, that the sewers overflow and have negative effects on the quality of the waterways. An example of this was witnessed in 2019 when a large storm took place in Philadelphia over labor day weekend. When this occurred, scientists measured the water flow and oxygen levels of Frankford Creek in Juniata Park. What they found was that as the water levels increased, the oxygen levels in the water decreased,a sign of depleted waterway health, jeopardizing the survival of aquatic wildlife. This example shed light on a growing problem in Philadelphia; antiquated Combined Sewer Overflows (CSOs) which are designed to overflow during storms into the waterways of the city. When conceived, the CSOs were less alarming and detrimental. However, as the population and frequency of precipitation increases, the systems have become dangerous (Kummer).

Not dissimilar to the way CSOs are damaging the city's waterways and littering them with human waste, nonpoint sources of pollution such as water drains deliver trash to the water systems which effectively harms wildlife and spreads waste around the city and beyond. . An

example of the magnitude of this problem can be witnessed in the clean-ups. In 2017, students and community members came together to clean up Bartram's Garden site. Over a period of two hours, 798 pounds of recycling, 12 tires, and 5,075 pounds of trash were collected on the shore of the Schuylkill river. The trash that doesn't flow into the waterways often gets clogged at the drainage sites. In preparation for Hurricane Ida, in September of 2021, Philadelphia Water Department crews cleaned out clogged trash from the over 75,000 storm drains in the city. The clogged drains have a detrimental effect on the flooding patterns of the city, especially as more frequent flash floods occur due to the changing climate (Briggs).

Although trash entering the waterways is a huge contributor to the water pollution problem, there are other forms of runoff that are particularly relevant and a problem in urban areas. Unlike rural and many suburban areas, urban areas have limited surface area that is not covered by concrete, buildings and pavement. Therefore, when it precipitates, water cannot soak into the ground and is instead carried off into the waterways through the aforementioned drainage sites. This increases the amount of runoff and pollutants entering the waterways. Some of the most prominent substances found in urban runoff include pesticides, road salt, viruses and bacteria, heavy metals and toxic chemicals from vehicles. These substances enter the waterways and then negatively affect the health of marine life, cleanliness of the drinking water and may also pollute recreational areas. Researchers suggest that urban runoff can be somewhat alleviated by using porous materials as an alternative to pavement and to engineer solutions into the city planning such as structural controls and infiltration opportunities (Environmental Protection Agency).

The risk of water pollution is detrimental to the health of humans and marine organisms. Although the Philadelphia Water Department has extensive efforts for accruing safe drinking water, many places on the globe are not as fortunate. According to the United Nations, 2.2 billion people worldwide lack access to safe drinking water. Furthermore, experts estimate that in under five years, more than half of the world's population will not be able to access the amount of water required to sustain health. Drinking water access is particularly concerning in Asia, Latin America and Africa where water pollution has worsened in most rivers since the 1990's. The sources of this water pollution range from agriculture pollutants to sewage and wastewater. Additionally, experts estimate that 4.8-12.7 million tons of waste, as in plastic and garbage, enter the ocean each year.

The plastics that enter the ocean deteriorate into microplastics and are eaten by fish, which in many cases are eaten by humans. Studies show that ingesting plastics can cause a range of health concerns for humans. Among these concerns include inflammatory reactions, metabolic disorders and oxidative stress which leads to cancer, diabetes and heart disease. The other pollutants of our water ways such as chemicals and sewage inflict health concerns in humans as well. Consuming water contaminated by sewage can result in typhoid, dysentery and polio. Ingesting chemical waste water pollutants such as pesticides and fertilizers can cause a multitude of life altering health concerns such as cancer, heart and kidney problems as well as damage to the immune and reproductive systems. Although the sources of water pollution vary and different forms of pollutants affect the human body differently, it is evident that exposure to a life source such as water, when polluted, can be detrimental to the life it is supposed to support (MediLexicon International).

Water Pollution and the World: How It Currently Exists Here and There

Unfortunately, water pollution isn't only a problem in Philadelphia or The United States. Pollution happens all around the world. It may look different from place to place based on the infrastructure, environment and lifestyles of the citizens. However, the effects of littering and water pollution, world-wide, are similar in that waterways and the environment are plagued by trash and waste. In order to incorporate a multicultural perspective, I think it is important for the content to be explored in the context of other parts of the world.

Research conducted in 2018 revealed that fish species in the Amazon River basins were ingesting plastics for the first time. This discovery demonstrates that littering of plastics in the Amazon River is growing and extending to areas where there aren't even high numbers of humans. The pollution is becoming detrimental to the wildlife who reside there. The research explains that plastic materials such as plastic bags, bottles and fishing gear are entering the river and then degrading over time into meso and micro plastics that fish species go on to digest. The research study examined 172 specimens of various fish species from the Xingu River Basin and found that one quarter of the specimens had ingested plastics of various sizes and types. The ingestions of plastic can cause internal injuries and blockages that can ultimately lead to death and starvation of the animal (Lucas-Solis).

Across the world in Thailand, the plastic pollution problem has been persistent and worsening. In 2015, Thailand was identified as the 6th worst plastic polluting country in the world in terms of volume of waste. In 2018, researchers identified tobacco waste products to be a huge issue along the coast. The researchers collected tobacco waste product data by sieving sand from 11 beaches along the coast of Thailand. The survey revealed 3067 cigarette butts in the beaches' lounge areas. The large amount of tobacco product waste not only affects the landlife and appearance of the beach but also toxifies the marine life as the litter is washed into the ocean, or thrown into the ocean by humans. As cigarette filters degrade, they break down into microplastic fibers that are detrimental to marine life in similar ways that the plastic found in the Xingu River Basin initiate trauma and death to the fish of the Amazon (Kungskulniti).

Although plastic litter has been a growing issue since the industrial age and growth in consumerism, the year 2020 brought a whole new form of plastic litter to the forefront around the world; disposable face masks and other personal protective equipment (PPE). As the Covid-19 pandemic continues, citizens worldwide are beginning to see the pollution effects, including surgical masks and PPE litter. When the words "Covid+Face mask+pollution" were searched on Google Scholar in August of 2021, 2731 results were registered. Thus, research is taking into account the effects that the global pandemic might have on wildlife in terms of exposure to litter and the effects of PPE pollution. To explore the effects of the pandemic on the amount of litter, a surveyor in Australia's New South Wales recorded observations about the amount of face masks and PPE littered in a rural area between November of 2020 and August of 2021. The results showed that during the mandatory mask wearing period, an average of 5.78 masks a day were observed compared to an average of .14 masks per day in the pre mandatory period. The majority of these masks were found in gutters and car parks while others were found on footpaths and streets. The research states that, "Single-use surgical face masks have been alluded to as 'the new cigarette butts' in their capacity to become a ubiquitous urban refuse item." It is arguably essential to heighten the awareness of surgical masks and other PPE litter as similarly

detrimental to the environment as other more aged forms of litter such as cigarette butts and plastic bags (Spennemann).

Trash and water pollution accumulation varies from place to place, but all continents of the world meet in the oceans where garbage patches continue to expand in size. Historically, the Great Pacific Garbage Patch has been the largest patch of marine trash in the world. It is so large that it has three different sections, the Eastern Garbage Patch, the Western Garbage Patch and the Subtropical Convergence Zone where debris moves from one patch to another. The garbage patch was formed by ocean currents carrying debris from trash hauls and other nonpoint sources which ultimately have gotten trapped in a nonbiodegradable vortex. Researchers have also learned that this debris often sinks to the ocean floor which makes the actual size of the garbage patch nearly impossible to measure. The garbage patch is not only unsightly but it also causes a lot of harm to the marine life and ultimately puts humans at risk too as plastics break down and are consumed by fish which are later frequently eaten by humans. Additionally, marine life other than fish are affected such as albatrosses and seals who get tangled in the trash or consume the plastic themselves. There is a concern about the whole marine life food web being disrupted because the vast surface area of the garbage patch obstructs sunlight from reaching autotrophs such as algae which provide energy to the rest of the communities food web. Although the harm of the Great Pacific Garbage Patch is severe, no nation will take responsibility for it so it continues to grow and persist. Scientists argue that eliminating non-biodegradable materials is one way to save marine life and clean up the vortex of trash (National Geographic Society).

Determining Factors of Water Pollution and Littering: But Why?!

In order to have a thorough understanding of pollution and its effects on the environment, it is necessary to understand the contributing factors to the act of littering; that is why some people might litter while others don’t, why littering happens more in some places than others , how the act of littering is perceived by different individuals and the larger contributors to trash pollution.

In 2020, a study was conducted in order to evaluate the relationship between temporal distance, a person's cultural identities and littering behavior. Temporal distance is the perceived difference in time between past and future events and the present. Temporal distance is thus influenced by culture because perception of time is shaped by the culture of the society that a person lives in. For example, individualistic societies tend to have a more monochronic perception of time than collectivist cultures. Therefore, collectivist cultures tend to have a more recent perception of the future. A study conducted to measure the relationship between littering, temporal distance and social norms focused on individuals from the United states (individualist culture) and South Korea (collectivist culture). The study used the format of a survey to give participants a series of questions and scenarios. Based on their answers, the researchers were able to measure any trends and patterns. What they discovered is that there was little difference between the two sets of respondents when it came to contra-environmental behaviors such as littering. However, South Korean respondents related more strongly to pro-environmental behaviors such as recycling which may be a reflection of their temporal distance to the effects of pro environmental behaviors (Park).

In addition to perception of time and social norms, studies suggest that personality may also play a role in an individual’s littering behavior. In 2019, researchers conducted a study in Nigeria that

tested whether or not there was a positive relationship between littering habits and personality traits such as agreeableness, extroversion, neuroticism and openness. What they discovered was a noteworthy association between littering prevention and the personality traits of extroversion, agreeableness, conscientiousness, neuroticism and openness. The implication of this study suggests that a person's personality may be able to predict their littering behavior (Opayemi).

Finally, studies suggest that the environment itself may play a role in individuals' littering behavior. A study conducted in 2013 centered on observations of 9,757 individuals from 130 different outdoor public spaces in the United States. What the study concluded was that individuals were more likely to litter when there was litter already on the ground and less likely to itter if there were trash receptacles available. Additionally, the closer the proximity of a person to the trash receptacle, the more likely the person was to dispose of the trash pro-environmentally. This indicates that environments that have more trash receptacles are less likely to have litter; which will, in turn, perpetuate pro environmental behaviors (Torgler).

However, inadequate trash collection, in and of itself, proves to be a perpetuating problem in Philadelphia that continues to largely contribute to the excess trash on the streets, clogged drainage sites and polluted waterways. The Covid-19 pandemic has only heightened the awareness of this issue. In a November 2021 Philadelphia Inquirer article the severity of the delays was laid out. The article states that, "trash pickup delays have gotten worse since the coronavirus pandemic hit, with the average on-time pickup rate falling to just 53% in fiscal year 2021." What that means is that Philadelphia residents are setting out their trash on the designated trash night and that there is just under a 50% chance that the trash will sit there for days on end until it is eventually picked up. This is not a fault of the sanitation engineers, but a reflection on the city government's priorities. Although the pandemic brought on new extreme delays for trash collection because of " a major increase in curbside tonnage, a workforce afflicted and impacted by the COVID-19 pandemic, and efforts to resolve staffing shortages" the trash collection in Philadelphia has been below standard for some time. Data shows that between years of 2009 and 2013 the city wide pick up rate was 94%. However, the rate dropped to 84% between 2014 and 2019. As such, Philadelphia has been experiencing delayed trash collection for nearly a decade.

In addition to the deterioration of the trash collection rate in the city, there is a gapping inequity of trash collection frequency between primarily white neighborhoods and neighborhoods where people of color live. The data shows that Center City, Fishtown and Northern Liberties have had the highest, and most consistent, rate of collection through the pandemic. However, the pandemic alone doesn't account for the systemic inequities that take place. The data shows that, "from January 2017 to February 2020, Center City and parts of the Northeast among the city's whitest neighborhoods experienced average pickup rates of 95% and 93%...while areas in Northwest Philadelphia, South Philadelphia, and West Philadelphia saw rates between 65% and 76%." The lack and limited frequency of trash collection leaves room for trash to escape the bins and litter the streets, especially with increasing inclement weather due to climate change. The effects of this are only heightened in neighborhoods who are historically oppressed, systemically disadvantaged and exposed to heightened levels of environmental health disparities (*Trash pickup delays surged in Philadelphia during the pandemic. But they weren't the same everywhere*).

Anti-Pollution Campaign and Design Solutions: How Can Things Change?

Historically, there have been many attempts and strategies for eliminating pollution and littering behavior. From legislation to catchy songs, pro-environmental behavior has been enforced and endorsed time and time again. This section will focus on attempts at preventing litter and water pollution, in particular; anti-littering education campaigns, trash can design, packaging designs and legislation.

In order to completely understand the effects of litter and littering behavior, individuals need to be exposed to the research and education surrounding the topic. Some individuals may litter simply because they don't know the consequences of their actions. However, it is important to consider that education programs alone may not be the sole solution to litter (Taylor).

In 2008, a research study was conducted in order to determine the effectiveness of trash can design in terms of eliminating littering behavior. The study aimed to activate personal norms in order to encourage disposal of litter into trash bins. The study used different trash can designs in order to determine which design would be most effective. The designs included a trash can with a mirror, a trash can with encouraging words, and a trash can with both a mirror and encouraging words. What the researchers discovered was that in all three conditions, people were less likely to litter. However, individuals were more likely to put trash in the trash bins with the explicit message of "litter here" and take the trash with them when the trash bin with the mirror was present. Either way, the study indicates that the designs of trash bins can significantly reduce litter in the environment of the receptacle (De Kort).

While the design of trash bins seemingly plays a role in the likelihood of someone to litter, research suggests that it is also important to consider the conditions of the packaging of products and how those conditions affect the likelihood that it will be littered. A study conducted in 2008 experimented with the design of packaging in terms of anti-littering labels, reclosable and reusable containers, and designs that keep proper disposal of trash at the forefront of peoples' minds. The research indicates that conspicuous anti-litter messaging may reduce littering, that screw on reusable containers are less likely to be littered and that there is no straightforward significance between targeted mindfulness of packaging and littering behavior. Simply put, the study served as a beginning point of analyzing how packaging design could affect littering behavior and that it is worthwhile to be investigated more thoroughly (Wever).

In recent years, reusable packaging has been on the rise as researchers, consumers and companies see the positive effects that switching to reusable options has on the environment. However, this shift is relatively new. Data shows that as of 2019, Unilever, Walmart, and Johnson & Johnson collectively used reusable plastic for less than 2% of packaging. However, data also demonstrates that the reusable packaging market for beauty and personal care products, specifically, grew by 65% from June 2020 to May 2021. This puts emphasis on the increasing popularity of reusable packaging for the products that people use frequently. One company, in particular, named Loop uses a system where products are delivered and used. Once the consumer is finished with the product, the container is mailed back to the company where it is washed and used again. Another strategy gaining popularity is the use of refillable stations at businesses like Target where consumers can bring their own reusable containers to purchase products like soap and detergent. Although reusable packaging seems like a perfect solution, researchers suggest

that important considerations need to be taken into account when designing the process of reusable packaging. For example, transportation of the reusable packaging back and forth between consumer and the business can add even more pollutants into the air and consumers need to be more extrinsically incentivized to return the packaging in the first place. Although packaging contributes to only 10% of production's environmental burdens, it is a small change that promotes more pro environmental behavior (Ducharme).

Locally, Philadelphia has taken measures to limit the use of plastic bags throughout the city by implementing a plastic bag ban. A Philadelphia news article states that, "according to the city, we collectively go through more than a billion single-use bags each year, the majority of them plastic." The substantive amount of plastic bag use has prompted city officials to start regulating the use of plastic bags at businesses. In late 2019 the bill first passed and was official put in place in July of 2021. The ban started with a slow roll out that started with businesses placing signage around establishments to make consumers aware of the change. As of October, there has been the expectation that no business in the city of Philadelphia will be using plastic bags. Starting in April of 2022 businesses will receive fines for not adhering to the law. However, the actual effectiveness of plastic bag bans on improving the environment is arguable. Although cities that have implemented bans on plastic shopping bags have seen a decrease in thee amount of plastic shopping bag waste, there is still an overwhelming amount of plastic bags being used as trash bags and the alternative to plastic shopping bags, paper bags, has a negative effect on the environment itself through the production process and admittance of greenhouse gasses into the atmosphere (Murrell).

Teaching Strategies

In order to steer away from the remedial tendencies of "pedagogy of poverty," and to support the full potential of Black students, educators need to consider more of a critical-reality pedagogy. Critical-reality pedagogy provides students the opportunity to engage in a challenging educational experience while exercising their capacity to fight for social justice. Theorist Paulo Freire, who in previous contexts coined the term "pedagogy of the oppressed" originally suggested a transition to a more "critical" pedagogical approach in order to help educate the oppressed fight for equity. He suggested that educators need to prepare their oppressed students to challenge the situation that oppresses them, instead of communicating ideals of the oppressor through antiquated learning capacities such as simply delivering information. He suggests that this is done through problem-posing. (Freire) That is, students are encouraged to identify problems in their lives or communities and create a plan of action, alongside their teachers. Within the realm of critical pedagogy, teachers become partners rather than distributors of information. Freire suggests a five step process that promotes student action and reflection on that action. The five steps are: identifying the problem, analyzing the problem, creating a plan of action, implementing the action, and analyzing the effect of the action. Throughout this whole process, it is expected that the students and teacher are committed, equally, to resolving the oppressing issue. (Duncan)

Historically, school curriculums and standardized tests have been built on antiquated state science standards that possess little relevance to the lives of the students. An approach to creating more equitable and culturally relevant science experiences for students is phenomenon based learning. Phenomenon based learning uses natural phenomena that occur in the real world to

drive inquiry and instruction. The phenomenon is particularly effective when it is discoverable in the students' lives, school or surrounding community and invites students to relate to the phenomena on a more personal level. Additionally, phenomenon based learning encompasses the Next Generation Science Standards and Engineering Practices that require students to engage in science using the skills required in STEM positions. Students experience phenomena and then use engineering practices to design solutions to problems that may arise from the phenomena. Through this process, students are building an understanding of the content and figuring it out on their own instead of being told or directed as to what to think about the content. Thus, students have agency over their learning and are able to create long lasting and transferable connections to the content. By introducing students to the content through phenomena discovered in class together, all students have equitable access to the phenomena as the base of prior knowledge that will be accessed for the remainder of the unit.

This unit will be combining the phenomenon based learning technique and critical reality pedagogy in order to provide students with the experience of figuring out why people litter, what the effects of littering and pollution are on the environment and how they can advocate for change. The unit will follow the sequence of phenomenon based learning that includes stages dedicated to asking questions and "figuring out" the content.

Lesson Strategies and Evaluation Tools

- Phenomenon Based Learning
- Collaborative Group Work
- Jigsaw Activities
- Webquests
- Presentations
- Discussions
- Demonstration
- Constructed Responses
- Non-Fiction Reading
- NGSS Science and Engineering Practices:
    - Asking questions and defining problems
    - Developing and using models
    - Planning and carrying out investigations
    - Analyzing and interpreting data
    - Using mathematics and computational thinking
    - Constructing explanations and design solutions
    - Engaging in argument from evidence
    - Obtaining, evaluating and communicating information

Unit Eligible Content, Standards and NGSS Performance Expectations:

- LS2.A - Interdependent Relationships in Ecosystems: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- S8.B.3.1.3 - Explain relationships among organisms (e.g., producers/consumers, predator/prey) in an ecosystem.
- S8.B.3.2.1 - Use evidence to explain factors that affect changes in populations (e.g., deforestation, disease, land use, natural disaster, invasive species).
- S8.A.1.1.2 Explain how certain questions can be answered through scientific inquiry and/or technological design.
- S8.A.1.1.3 Use evidence, such as observations or experimental results, to support inferences about a relationship.
- S8.A.1.1.4 Develop descriptions, explanations, predictions, and models using evidence.
- S8.A.1.2.2 Identify environmental issues and explain their potential long-term health effects (e.g., pollution, pest controls, vaccinations).
- S8.A.2.1.4 Interpret data/observations; develop relationships among variables based on data/observations to design models as solutions.
- S8.A.2.1.5 Use evidence from investigations to clearly communicate and support conclusions.
- S8.A.2.1.6 Identify a design flaw in a simple technological system and devise possible working solutions.
- S8.A.3.2.2 Describe how engineers use models to develop new and improved technologies to solve problems.
- MS-ESS3-3 Earth and Human Activity: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Classroom Activities

Pollution, Littering and Our Waterways: Introduction and Health Concerns

Lesson 1; Anchoring Phenomenon Routine: How does littering and water pollution affect the health of organisms and how can it be eliminated?

(Approx. Time: 3-45 minute periods)

The unit will begin with an anchoring phenomenon that will drive the remainder of the unit. Students will be shown the images of the causes and effects of water pollution. Students will be required to make observations about the images and create a list of "I Wonder" statements that will be used to drive the content and inquiry moving forward.

In addition to the presentation of the anchoring phenomenon, the anchoring phenomenon routine includes stages that require students to make personal connections to related phenomena they experience in their own lives. This stage of phenomenon based learning takes place as a whole class. Students will share out the column of the anchoring phenomenon organizer and make connections to what they observed in the images and data. As a class, create a list of "related phenomenon" that you can post on the wall of the classroom (see example in the appendix) for students to reference as they work through the unit and figure out the content.

Next, students need to create initial models. In this unit, students will model the sources and effects of water pollution. The initial models will be shared in a gallery walk and then, the class as a whole will create a consensus model that harnesses the main ideas from the individual initial model of each student. This format allows students to think and model independently and then make connections to each other. This gives students the opportunity to take ownership of their learning and make stronger connections to the content than if they were told what happens to the litter as it enters the waterways.

After exploring the anchoring phenomenon, making connections to related phenomena and creating initial models, students will start to create a list of questions that they have about the images and data. From their list of questions, students will plan ways that they can investigate the questions and discover information that contributes to the overarching question of the unit, as a whole.

Materials:

- Anchoring Phenomenon Organizer (link)
- Anchoring Phenomenon Reference (link)
- Initial Model Template (link)

Evaluative Tool:

- Discussion about initial understandings of the anchoring phenomenon and the initial model

Lesson 2; How Has Waterway Pollution in Philadelphia Changed Over Time?

(Approx. Time: 1-45 minute period)

Students will engage in a jigsaw activity in order to research collaboratively and communicate about the ways water pollution has changed over time in Philadelphia and The United States. Students will first research their time period in history and then teach their classmates about it. Students will then work together to create a timeline of how different government entities have attempted to eliminate and regulate waterway pollution.

Objective(s):

- *Students will be able to* understand the history and importance of the Philadelphia water system as well as the water legislation *in order to* explain how society targets waterway pollution through infrastructure and law.

Materials:

- History of Eliminating Waterway Pollution Jigsaw Activity (link)

Evaluative Tool:

- Collaborative discussion of history

Lesson 3; What are the Different Sources of Littering and Water Pollution? How Do They Affect Our Environment?

(Approx. Time: 3-45 minute periods)

This lesson will focus on the different sources of water pollution in urban areas. Students will first witness a demonstration conducted by the teacher that shows how different sources of water pollution show up in waterways. Then, students will collect their thoughts and consolidate information about the sources of pollution through an interactive online simulation, article and sewer overflow data.Students will work collaboratively while analyzing the sources of information and make predictions about how climate change might alter the sources of water pollution. Finally, students will create a model that represents what they learned.

Objective(s):

- *Students will be able to* understand the different sources of water pollution and the effects on our waterways *in order to* model how climate change can make these circumstances worse.

Materials:

- Water pollution awareness demonstration:
- https://www.carolina.com/teacher-resources/Interactive/water-pollution-awareness-demonstration/tr40105.tr
- Sources of Water Pollution Graphic Organizer (link)
- Climate Change and Pollution Sources Model (link)

Evaluative Tool:

- Climate Change and Pollution Sources Model

Lesson 4; How Does Water Pollution Affect Human Health?

(Approx. Time: 3- 45 minute periods)

This lesson will use an online resource to introduce students to the ways that different water pollutants affect the human body. Students will then choose one of the health effects of water pollution and research it more in order to explain how the water pollutant affects the body systems.

Objective(s):

- *Students will be able to* understand how different pollutants in the water affect human health *in order to* explain the long term effects of exposure to polluted water on the body systems.

Materials:

- Water Pollution and the Effects on Health (link)

Evaluative Tool:

- Discussions and presentations about water pollution effects on health

Water Pollution and the World: How It Currently Exists Here and There

Lesson 5; How Do Different Parts of the World Experience Littering and Water Pollution?

(Approx. Time: 4-45 minute periods)

This lesson will be formatted in a choice board. Students will be able to read about either Brazil, Thailand or Australia. As mentioned in the Unit Content section of this plan, these three areas of the world are experiencing littering in their own ways. In Brazil, microplastics are showing up in the digestive tracts of fish in the Xenu River Basin. In Thailand, cigarette butts are plaguing the beaches and affecting marine life in toxic ways. In Australia, mask litter from Covid-19 masking mandates is increasing. The students will have an opportunity to choose which part of the world they want to focus on. Then, students will complete a webquest that guides their thinking while they research the environment of their chosen part of the world, the legislature in place for protecting the waterways and wildlife and how humans in those areas perpetuate littering. Students will then consider how the littering that takes place in their chosen part of the world contributes to pollution worldwide.

Objective(s):

- *Students will be able to* analyze data and research from different areas of the world *in order to* understand water pollution as a global problem and make connections to the littering and pollution they experience in their own communities.
- *Students will be able to* explore the causes and effects of water pollution in different areas of the world *in order to* answer a constructed response.
- Materials:

- Choice Board (link)
- Articles and Constructed Responses (link)

Evaluative Tool:

- Constructed response

Lesson 6; What are Oceanic Garbage Patches and How Do They Affect Marine Life?

(Approx. Time: 3-45 minute periods)

This lesson will focus on the Great Pacific Garbage patch in order to expose students to how pollution and trash accumulate offshore. Students will read about the Great Pacific Garbage patch and create a newsletter that spreads awareness of the causes and effects of the Great Pacific Garbage patch.

Objective(s):

- *Students will be able to* analyze the causes and effects of the Great Pacific Garbage Parth *in order to* create a newsletter to spread awareness.

Materials:

- Research Organizer (link)
- Newsletter Template Links:
    - https://www.adobe.com/express/discover/templates/newsletter

Evaluative Tool:

- Final Newsletter

Lesson 7; What Plastics Are In My Community?

(Approx. Time: 2- 45 minute period)

In this lesson, students will conduct their own research about the different types of plastic that are found in the school and surrounding areas. Students will collect data about the plastic and make connections to how this plastic can end up in the ocean by also locating the drainage stations. Students will collect data and present visual representations of their findings.

Objective(s):

- *Students will be able to* collect and analyze data on plastic litter in their communities *in order to* predict how the plastics from their community ends up in the ocean.

Materials:

- Plastics In My Community Data Collection and Analysis in Notebooks

Evaluative Tool:

- Presentations and discussion of student findings

Determining Factors of Water Pollution and Littering: But Why?!

Lesson 7; Why Do People Litter?

(Approx. Time: 1- 45 minute period)

This lesson will require students to investigate the reasons for littering. Students will research the different reasons people may litter including cultural norms and proximity to the problem and trash receptacles. Students will start by interviewing each other and finding out about the reasons their classmates may, or may not litter. Then, students will create a survey independently for the school. Students will compare their individual surveys to the surveys of their peers and then compile a consensual list of questions as a class. This survey will be given out to the students of the school and the results will be analyzed in order to gain a sense of why students in the school litter.

Objective(s):

- *Students will be able to* identify the determining factors of littering *in order to* prevent littering in their school and surrounding community.
- *Students will be able to* investigate the student body's habits around littering *in order to* make conclusions about peer littering behavior based on data collected.

Materials:

- Student Created Interview Questions
- Student Created Survey
- Analysis of Data in Notebooks

Evaluative Tool:

- Analysis of data and discussion

Lesson 8; How Does Trash Collection Contribute to Water Pollution and Litter?

(Approx. Time: 1-45 minute period)

In this lesson, students will analyze data about trash collection from different time periods and different parts of the city. Students will then identify any trends in the data and make connections to how patterns of trash pick up affect pollution and excess trash in the community. Students will collaborate and come up with ways that this could potentially affect water pollution on a global scale.

Objective(s):

- *Students will be able to* analyze trash collection data throughout the city and overtime *in order to* identify patterns and trends that contribute to environmental conditions and pollution.

Materials:

- Data on Trash Collection Organizer (link)

Evaluative Tool:

- Collaborative discussion on how trash collection patterns contribute to worldly water pollution

Anti-Pollution Campaign and Design Solutions: How Can Things Change?

Lesson 11; Cumulative Lesson

(Approx. Time: 5-45 minute periods and time at home)

This lesson will give students the opportunity to either design an anti-littering campaign or create a packaging prototype to eliminate littering and encourage pro-environmental behaviors. Students will be given the choice to work collaboratively and create an anti-littering campaign for the school and community. Or, students will work collaboratively to create a prototype design for eliminating littering behavior.

Students who chose to focus on the anti-pollution campaign will research the pro-environmentalism campaigns that have taken place in the school district and in the surrounding areas, in addition to world wide campaigns. Students will analyze what the elements of the campaign were and whether or not they were effective. Students will then use the information that they accumulate in this lesson to assist them in making their own campaigns that are focused on either urban runoff, littering in the school or plastic use.

Students who chose to focus on creating a prototype for sustainable packaging will begin by creating a list of things that they use that are plastic and think through which of those things could be reusable. Then, students will go through the engineering design process and create a prototype using different materials to represent their idea for sustainable packaging. Students will collect data on feedback for their design and make revisions based on recommendations and flaws.

Objective(s):

- *Students will be able to* research the elements of current and former pro environmental campaigns *in order to* create their own campaign for the school and surrounding community.
  OR
- *Students will be able to* use the engineering design process *in order to* create a solution to littering.

Materials:

- Pro-Environmental Campaign Research Organizer Template (link)
- Sustainable Packaging Prototype Research Organizer Template (link)

Evaluative Tool:

- Pro-Environmental Campaign OR Sustainable Packaging Prototype Presentation

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