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No Guts, No Glory

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Introduction

Ignorance is a gift, for ignorance leads to a path of discovery. "To know you know nothing is in its self to know much". I heard this line from a TV episode of Kung Fu many years ago and it always stayed in my mind. I assume it is a slight misquote from Confucius' "To know that you know nothing. That is the meaning of true knowledge".Along the same lines, Socrates said "The only true wisdom is in knowing you know nothing." In Stuart Firestein's book *Ignorance, How it drives Science,* a case is made that science deals in lack of knowledge. The process of searching for answers is more important than actually finding often elusive answers. Science usually produces more questions: often many more questions than answers. I always tell my students I want them to be comfortable with being uncomfortable. Firestein recommends "uncertainty without irritability." He argues that we are most imaginative when we are the most uncertain. I think this state is important for critical thinking skills and the scientific process in general. Science is much more than an accumulation of facts and it is seldom an orderly sequential process. Even Einstein said that imagination is more important than knowledge! The idea of discovery is a Platonic view that the world can be investigated and we can eventually learn about everything in it by asking questions. Plato was a student of Socrates.

Rationale

"Without a science-literate population, the outlook for a better world is not promising," says former astronaut George D. Nelson, director of the American Association for the Advancement of Science's Project 2061. Ideally, California and the nation would like to regain a leadership role in the fields of science, medicine, and technology. It is said that our economy and security depend on it. At the university level, enrollment in STEM majors (STEM stands for Science, Technology, Engineering and Math) and the pursuit of science or STEM-based careers has failed to keep up with the national and worldwide demand for a scientifically literate population. This pursuit for science literacy has been emphasized my entire teaching career, and yet my class size has never been below 32 students. If science is deemed important let's lower class size to meet student needs. I now have three science preps instead of one or two lab based classes to prepare for. Some believe that No Child Left Behind did in fact leave science behind as it is not a core tested subject. Science, although deemed important by many, has been cast aside and neglected in many educational settings.

Students who might have been previously interested in science have lost interest by the time they have reached high school. I teach at a large suburban high school just outside of San Francisco, California. Our community has small town culture and we are not very sophisticated in our exposure to real science. Twenty percent of our school population is recorded as being socioeconomically disadvantaged but I get the impression that is not accurate. I would estimate that this figure is actually much higher.

Twenty to thirty percent of my students are eligible for academic assistance based on special needs. Last year I co-taught one biology section with a special education teacher to address some of those needs in a pilot program. The academic abilities in each biology section tend to be diverse with students who can function above grade level, at grade level and below grade level in math and reading. Some are at first grade level. According to the 2011 California state testing standards twenty five percent of the tenth graders scored below basic or far below basic in biology while thirty two of the eleventh graders scored below basic or far below basic in earth science. Both these courses are needed to graduate in my district.

Many students, unfortunately, perceive the study of science (biology in particular) as the acquisition of a huge array of information. As they get older they tend to forget their innate curiosity for the natural world and sciences in general. They see science as a large textbook of knowledge they are required to remember and a class they must struggle with in order to pass and graduate. The vocabulary is new and difficult, as are the concepts. I intend to give my students a historical context of the concepts of biology as a strategy to spark their interest and motivation. I also want to share with them the hardships of various scientists before and after major breakthroughs. I think many see scientists as pampered and privileged members of society, and this is rarely so, especially in the past where many trudged on in poor conditions with little funds.

I want them to understand that biology is a process of discovery through investigations that have occurred over a span of many years. Sometimes information has been gathered not only through decades, or a generation, but through multiple centuries. The nature of science is cumulative. Only through hard work, perseverance, dedication and luck, have breakthroughs and discoveries been made. Success in biology requires asking meaningful questions with an inquisitive mind, overcoming various obstacles and pressing on without support.

Most, if not all, of my students want answers and results to be predictable. They tend to get upset if their data is unexpected or if the results are not predictable and obvious. They feel comfortable doing cookbook science and being spoon-fed information. Even though there is much pressure to teach this way, I want them to experience science. I desire my students to be engaged and motivated to ask their own meaningful questions, design investigations and be comfortable with being uncomfortable. In view of the above, my unit is one in which students will explore how each of the following people engaged in the scientific process to arrive at their conclusions, discoveries, breakthroughs and/or theories: Socrates, Rosalind Franklin, Rachel Carlson, Louis Pasteur, Antony van Leeuwenhoek and Jean Baptiste Lamarck.

After a strong exposure to the work and tribulations of these great minds, I will encourage the students to be active learners challenged with problem solving and critical thinking. Ultimately, I want my students to develop the confidence to keep plugging away at problems or questions. By highlighting selected scientists and/or breakthroughs that have made significant contributions to the field of biology, students will understand the process of science. Discoveries have not come quickly or easily. Only through years of labor and a dose of luck have scientists helped us understand the world we live in. Perseverance over time is the theme of my curriculum project.

My curriculum project will be an ongoing theme that spirals throughout my course curriculum over the span of the school year. My biology sections contain mostly 10 th graders who are the target population for this curriculum, but I can apply it to 11 th grade physiology and 9 th grade health, as well.

History and Background

Socrates

The classical Greek, Athenian philosopher, Socrates(469 BC – 399 BC), is credited as one of the founders ofWestern philosophy. Socrates is renowned for his contribution to the field ofethicsand theSocratic Method, orelenchus. The Socratic Method remains a commonly used tool in a wide range of discussions, and is a process in which a series of questions are asked not only to elicit an answer but sometimes more importantly to encourage fundamental insight into the topic up for discussion. Socrates also made important and lasting contributions to the fields ofepistemologyandlogic. The influence of his ideas and approach remains strong in providing a foundation for Western philosophy including the scientific process.

Epistemologyis a termrelated to the nature and scope (limitations) of knowledge to address these questions:

- What is knowledge?

- How is knowledge acquired?

- To what extent is it possible for a given subject or entity to be known? [1]

Much of this field, whose roots can be traced back from Socrates, has focused on analyzingthe nature of knowledge, especially how it relates to related ideas such as truth and justification. Socrates' most important contribution toWesternthought is thedialecticmethod of inquiry, which is also known as theSocratic Method. In ancient times, Socrates applied this method to the examination of key moral concepts. Plato describes this methodin theSocratic Dialogues: a problem is broken down into a series of questions. The answers to each of the questions would gradually distill or narrow down the answer sought. The impact of this approach can be seen today in the use of thescientific method. Thehypothesisis the first stage. The development and practice of this method is one of Socrates' lasting and most important contributions. It is also a key factor to all of the main themes inWestern philosophy. The original goal of the Socratic Method was to pose a series ofquestionsintended to assist in determining underlyingbeliefsand extent of knowledge. This method is anegativemethod ofhypothesiselimination, which is used in science today. Systematically, more accurate hypotheses are formulated while those that lead tocontradictions are eliminated. Originally designed to force an examination of the validity of one's beliefs, it has had a profound impact on Western thought.

Socrates once said, "I know you won't believe me, but the highest form of Human Excellence is to question one's self and others." [2] The development and practice of this method is one of Socrates' most enduring contributions. It is a significant factor in earning his place as the father of all the central themes inWestern philosophy. The influence of the Socratic Method continues to be strongly felt today in the use of thescientific method. There is a chart comparing the Socratic and Scientific Method in the appendix.

A young poet charged Socrates with the capital crime of irreverence. He was accused of failure to show due piety towards the gods of Athens and corrupting the youth of Athens. Socrates, as a citizen, had the right to go into exile voluntarily. He could have avoided the trial and punishment. He did not. Socrates stopped on his way to a preliminarily hearing to talk to some youth about mathematics and knowledge. He willingly drank poison hemlock without duress in the summer of 399.

Socrates dared to live a lifestyle independent of society's expectations. Ignoring the standards for respectful or professional appearances in his time he wore his hair long, like they did in Sparta (Athens was at war against Sparta). He went about barefoot and unwashed, carrying a stick. He did not seem to mind living in poverty but enjoyed his intellectual lifestyle seeking justice and goodness in knowledge.

Antony van Leeuwenhoek

Antony van Leeuwenhoek was one of the most unlikely and original scientists ever. His discoveries revolutionized natural history. Coming from a trade background, he had no family or personal fortune. He did not have a higher education or university degree. He spoke only one language:Dutch. Most scientists of the day knew Latin, Greek and their native language. These points would definitelyhave been enough to exclude him from the scientific community of his time period completely. Yet, with his exceptional observational and descriptive skills, careful diligence, ability to build a unique precision instrument, and an endless amount of curiosity, he was able to view a world no one else in history had seen before. His lack of affiliation to a university or local academic circle provided the luxury of being able to have an open mind free of the scientific dogma of his time. He had no obvious restrictions on his activities and because he was somewhat socially isolated, having no peer pressure. Having more than usual academic and personal freedom, he had time to pursue his passions.

Leeuwenhoek succeeded in making some of the most important discoveries in the history of biology, roughly three hundred years ago. He was the first to discover bacteria in 1676. He was also the first to seeprotists, sperm cells, blood cells, and many, many more things over the course of forty or fifty years of investigations. [3] He viewed these many microscopic specimens by making his own magnifiers and lenses: a process he kept to himself. His observations and deductions were widely circulated in letter form. These brought an entire world of microscopic life to the awareness of scientists. He sent many of his vivid and natural observations to the Royal Society in London.

Leeuwenhoek was bornin Hollandon October 24, 1632. His father was a basket-maker, while his mother's family were brewers. At the age of sixteen Antonywasapprenticed in a linen fabric merchantshop. He married and had four children but only one child survived beyond childhood. Fabric merchants used an instrument to evaluate the fabric under a magnifier to closely examine the threads.

By 1668, Antony van Leeuwenhoek learned to grind lenses, make simple microscopes (which were actually magnifiers), and began observing with them. He was inspired after a trip to London in the same year. There he was able to view a copy of Robert Hooke's illustrated book *Micrographia*. This extremely beautiful book depicted Hooke's own observations with the compound microscope (including cork cells). It was a popular academic accomplishment during this period. This book must have inspired Leuwenhoek. I have viewed a copy of *Micrographia* at Yale University: it is very detailed and amazing. In the preface of *Micrographia* is a design for a simple lens microscope. Leeuwenhoek could not afford a professionally tooled standup table top scope like others of his time used. He was an amateur with enthusiasm and so had to make do with what he could build himself. The advantage of the single lens scope was clarity. There were distortions with the compound scopes of the time. The disadvantage is that they are difficult to use unless one had great skill and patience. He was a master at adjustments and lighting.

Leeuwenhoek is known to have made hundreds of "microscopes", although less than ten have survived to the present day. All of Leeuwenhoek's known instruments were simple powerful one lens scopes. A drawing of one of Leeuwenhoek's "microscopes" is in the appendix. The single lens is mounted in a tiny hole in a brass plate. The plate makes up the body of the instrument. The specimen was mounted on the end of a sharp point or specimen holder in front of the lens. The position and focus could be adjusted by turning the two or three screws which manipulated the subject slightly to get it into a fine focus. At three to four inches long, the entire microscope/magnifier was very small especially compared to compound microscopes. Unlike the table top microscopes others used, and still use to this day, these had to be held up very close to the eye on or near the cheek. They required good lighting and great deal of patience to use. [4]

The early table top, compound microscopes were very difficult to build with the available technology. Additionally, they had limits in their clarity and magnifying power.

There was distortion enhanced by the two lenses. During this time period, they were not practical for magnifying objects more than twenty or thirty times.

Leeuwenhoek's unique skills at grinding lenses together with his naturally acute eyesight and his other various self taught skills allowed him to see many things for the first time. Antony van Leeuwenhoek was able to see clearer and brighter images than any of his colleagues could achieve. He was what my peers call a Maker: a person who can problem solve, figure things out and build things on their own. He made his own unique instruments but did not share them while he was alive.

What further distinguishes him from his peers was his curiosity to observe almost anything that could be placed under the lens, and his excellent ability to describe what he saw. In 1674 he noticed something interesting growing on the surface of a lake he was crossing. He collected a sample in a vial. When he viewed the sample with a scope he saw structures similar to human hairs with a green spiral spanning the width. He had discovered the alga Spirogyra. Although he himself could not draw well, he hired a professional illustrator to do the drawings of his observations to accompany his written descriptions.

Leeuwenhoek was highly regarded among the scientists for consistently and objectively communicating his interpretations prefacing them with "*but I imagine*", "*I figure to myself*", or "*so it seems to me*" Very few scientists have had such a clear definition of the line between observation and theory, fact and conjecture, real and implied. "*Yet he always presents his results in a way which, despite the imperfections of his language and his lack of scientific education, is a model for all other workers. He never confuses his facts with his speculations. When recording facts he invariably says "I have observed ..."*, wrote Clifford Dobell, 1922.

Leeuwenhoek was a gifted and seemingly humble man who made many discoveries about nature. He passed away at the age of ninety, still engaged in microscopy: examining gold bearing sands for a client in the East India Company. He is remembered in the scientific community for founding the studies of protozoology and bacteriology from scratch.

Jean Baptiste Lamarck

Jean Baptiste Lamarck (1744-1829) started out as a botanist and later became a zoologist. He was the eleventh child from an impoverished family from Picardy, France. He was destined for a career in the church as his father dictated. But when Lamarck was fifteen his father died and he was free to choose to go into the military. In 1763, while in Monaco, he became fascinated by natural history, especially botany. After four years in the military, he worked as a bank clerk in Paris, studying botany in his spare time. Attending classes and discussions, he wished to discover nature's true and distinct order. In 1778 he wrote *Flore Francaise*, a scientific book with a difference. In this book he introduced the common names for plants, instead of Latin names. This was for the intention of making science available to everyone. He also provided a dichotomous key. A dichotomous key is a two choice system used to identify a plant (or an animal). This type of key is used commonly today for identification for biology. Lamarck collected and sold shells to supplement his meager income. He was a middle class scientist.

After the French Revolution, a time of chaos to say the least, he was hired to become a curator of invertebrates including worms. At this time, he had remarried and his second wife was pregnant with his seventh child. His station of life was not impressive to other academics of the day. Worm study did not have the same professional status as that of vertebrates. Lamarck was not discouraged. He placed his heart and soul into his work on invertebrates accomplishing great things. Lamarck revolutionized our understanding of these creatures. He reclassified the invertebrates, which is a term he invented, into seven different classes. These are in use to this very day. He was the first to separate the *Crustacea*, *Arachnid* and *Annelida* from the "*Insecta*". Lamarck also broke with tradition in removing the tunicates and the barnacles from the *Mollusca*. This was no easy task as they are many more invertebrates compared to vertebrates. Lamarck emphasized inter-connectedness of all organisms. He saw life as being organized from simple to complex. He originated the term Biology!

By 1818 Lamarck was almost blind. Passing away in 1829, Lamarck deserves to be remembered in biology classes as a great zoologist and a forerunner of evolution. He was the first to introduce a systematic presentation of evolution. Unfortunately, he is most remembered for an incorrect theory stated as laws in *Philosophie Zoologique.* [5] These laws describe the doctrine of inheritance of acquired characteristics. Scientists of the time were immortalized by eulogies written by another prominent scientist. These had the power to sanctify the individual and their work or to assassinate a person's academic reputation. Georges Cuvier, a French anatomist harshly accused Lamarck of being a person with an over active imagination that led to conclusions that were highly questionable. [6] He was depicted as an academic rebel with no attachment to systems complying with the ideas that prevailed in science at the time (Darwinism). This was a damming assessment from someone as distinguished and respected as Cuvier. Lamarck's contributions to biology have suffered throughout history because he was an independent thinker who made one mistake, or might even have been misinterpreted. Unfairly, he was criticized even after his death. He received a poor man's funeral and was buried in a rented grave. After five years his body was removed. He is known as the scientist who was wrong about evolution. He deserves better.

Louis Pasteur

Louis Pasteur was born on December 27, 1822, in France, into a family of poor tanners. He was an average student in his early years, but was gifted in drawing and painting. At the age of fifteen he made pastels and portraits of his parents and friends. After a short time as professor of physics at Dijon Lycée in 1848, he became professor of chemistry at the University of Strasbourg. This is where he met and courted his wife. They had five children, only two of whom survived to adulthood. Sadly, the other three died of the bacterial disease typhoid. These personal tragedies may have inspired Pasteur to try to find cures for diseases such as typhoid.

Pasteur demonstrated that fermentation is caused by the growth of micro-organisms. Dating back to ancient times, it was thought that the growth of bacteria in nutrient broths was due to spontaneous generation: an idea Greek in origin. Pasteur promoted the concept of biogenesis (*Omne vivum ex vivo* "all life is from life"). [7]

Louis Pasteur placed boiled broths in various vessels. Some had swan necks so air could circulate but a filter and the shape of the tube would prevent particles or dust contamination from entering the broth. The broths only spoiled when the flasks were open to the air in which case particles could land directly on the broth. Therefore, he deducted that the living organisms that grew in such broths came from outside rather than spontaneously generated from within the broth. This was one of the most important experiments disproving the theory of spontaneous generation. This experiment also supported the germ theory. While Pasteur was not the first to propose germ theory, he was the one to fully develop it conducting many experiments that clearly supported it. He was also successful in convincing/educating most of Europe that micro-organisms are the cause of many diseases. [8]

Pasteur's research also showed that the growth of micro-organisms was responsible for spoiling beverages. [9] With this established, he invented a process in which liquids such as milk were heated to kill bacteria and molds present within them. He completed the first test on April 20, 1862. This process was soon afterwards known as pasteurization. Beverage contamination led Pasteur to the idea that micro-organisms infecting animals and humans might cause disease. He proposed preventing the entry of micro-organisms into the human body, leading to the future development of antiseptic methods in medicine and surgery.

In 1865, two parasitic diseases were killing great numbers of silkworms at Alais (now Alès). After several years of work, Pasteur proved it was a microbe attacking the silkworm eggs causing the disease. Afterwards, they were able to eradicate the disease. Pasteur also discovered anaerobiosis, whereby some micro-organisms can develop and live without air or oxygen. This was called the Pasteur Effect. Ernest Renan said of Pasteur's method of research, "This marvelous experimental method eliminates certain facts, brings forth others, interrogates nature, compels it to reply and stops only when the mind is fully satisfied. The charm of our studies, the enchantment of science, is that, everywhere and always, we can give the justification of our principles and the proof of our discoveries."

The pattern of logic in Pasteur's scientific career and the brilliance of his experimental method are well documented. Later in his career, he was approached with a contamination problem in alcoholic fermentation, which was thought to be an entirely inorganic chemical process at the time. After careful examination, he predicted that fermentation was a biological process carried out by microorganisms. This hypothesis was followed by many impressive experiments that showed unequivocally the existence of microorganisms and their effect on fermentation.

Another significant discovery facilitated by the germ theory was the nature of contagious diseases. Pasteur suggested that if germs were the cause of fermentation, they could be the cause of contagious diseases as well. This proved to be true for many diseases such as potato blight, silkworm diseases, and anthrax. After studying the characteristics of germs and viruses that caused diseases, he and others found that laboratory manipulations of the infectious agents can be used to immunize people and animals. [10] The discovery that the rabies virus had a lag-time before inducing disease prompted the studies of post-infection treatment with weakened viruses. This treatment was successful and has saved countless lives.

Rachel Carson

"...we have brought into being a fateful and destructive power". Rachel Carson was one of the world's foremost leaders in conservation. Her work as an educator, scientist and writer revolutionized America's interest in environmental issues. She was born in a small rural Pennsylvania community near the Allegheny River, where she spent a great deal of time exploring the forests and streams around her farm. In 1925, Carson entered Pennsylvania College for Women as an English major to become a writer. She switched to biology midway through her studies. After graduation, she was awarded a scholarship to complete graduate work in biology at Johns Hopkins University in Maryland. This was an enormous accomplishment for a woman in 1929.

Carson's talents in writing and biology led to a fifteen year career with the U.S. Bureau of Fisheries (now the U.S. Fish and Wildlife Service). Meanwhile, she continued to submit writings on conservation and nature to newspapers and magazines, urging people to regulate the "forces of destruction" and consider always the welfare of the "fish as well as that of the fisherman." During her free time, Carson wrote books about her government research. Her first book, *Under the Sea-Wind* published in 1941, highlighted her unique ability to present deeply intricate scientific material in a clear poetic language that captivated many readers and sparked their interest in the natural world. *The Sea Around Us* was published in 1951 and remained on the *New York Times*' best-seller list for 81 weeks. After the success of her second book, Carson left her position with the Service in 1952 in order to devote all her time to writing. She also wrote *The Sea Around Us* and *The Edge of the Sea*, published in 1956, providing a new perspectives on conservation to a concerned public.

Carson's future work would kindle an environmental revolution. Her final book, *Silent Spring*, published in 1962, awakened society to its responsibility as a cohabitant of the planet. Carson who had long been aware of the dangers of chemical pesticides knew of the controversy within the agricultural community as well. She had expected and hoped someone else would publish an expose' on DDT. She came to the realization that she was one of the few who had the appropriate background as well as the economic freedom to do it. *Silent Spring* provoked an enormous amount of controversy as well as attacks on Carson's professional integrity. Although she did not urge the discontinuation of pesticides, the pesticide industry reacted defensively and mounted a massive campaign to try to discredit her. She strongly recommended research to ensure pesticides were used safely and to find alternatives to dangerous chemicals such as DDT.

Afterwards, the federal government ordered a complete review of the pesticide policy. Carson was asked to testify before a Congressional committee. As a result of the review and her testimony, DDT was banned in the United States. Ironically the United States still manufactured DDT to sell in other areas of the world. [11] With the publication of *Silent Spring*, Carson is credited with initiating the contemporary environmental movement. Carson said that "man's endeavors to control nature by his powers to alter and to destroy would inevitably evolve into a war against himself, a war he would lose unless he came to terms with nature." She died from cancer in 1964 at the age of 57. Her book *Silent Spring* is now a classic topic in Advanced Placement Environmental Science classes all over the world.

Rosalind Franklin

Rosalind Franklin was apioneering molecular biologist.There iscontroversy surrounding her life and especially her research. The controversy continues to this day. She was responsible for a significant amount of the research and lab work that led to the understanding of the structure of DNA or deoxyribonucleic acid. The story of DNA involves more than a little competition and intrigue. Many believed Linus Pauling would decipher the structure of DNA, but he incorrectly thought it might be a triple helix instead of the actual double helix structure and was beaten to the finish in the end. [12]

Franklin was a very logical and precise person who excelled at science. She was fortunate to attend one of the few girls' schools in London that taught physics and chemistry. Imagine girls learning physics and chemistry!

When she was only 15, she knew she wanted to be a scientist. But, her father was not supportive of higher education for women, and refused to pay her way through college. Economic status was not the issue. An aunt offered to pay for her college education while her mother attempted to soften her father's objections. He expected Rosalind to be a social worker which was seen as an appropriate career for intelligent women of the day.

Ultimately he relented, as she graduated in 1941 from Newnham College, Cambridge.

She held a graduate fellowship for a year, quitting in 1942 to work at the British Coal Utilization Research Association. It was there that she did studies of carbon and graphite microstructures. She published five papers on the subject by the age twenty six. Her work is still quoted today, helping begin the field of high-strength carbon fibers. She studied the nature of coal and charcoal and how to use them most efficiently. This work was an important contribution to her country after World War II. After earning a doctorate in physical chemistry from Cambridge University in 1945, she spent three years (1947-1950) in Paris at the "Laboratoire Central des Services Chimiques de L'Etat." This is where she learned X-ray diffraction techniques that would later be useful in helping to determine the structure of DNA. She used x-rays to create images of crystallized solids. But, she pioneered the use of this method in analyzing complex, unorganized matter such as large biological molecules. In 1951, she returned to England as a research associate in John Randall's laboratory at King's College, London.

It was in the Randall's lab that she came into contact with Maurice Wilkins whose skills and research work was similar. Apparently, she and Wilkins led separate research groups and had separate projects, although both were concerned with DNA. When Randall gave Franklin responsibility for her DNA project, no one had worked on it for months. When Willkins returned from a vacation he actively misunderstood her role or pretended like he misunderstood her role. I am sure she did not fit in with the popular idea of a serious researcher. Even her father was hesitant to accept her career path. It would have been difficult for a woman, even a brilliant woman, to be accepted in this circle of elite scientists. Willkins treated her like a technical assistant and not as a respected peer. He also might have seen her as infringing on his territory. She has been described as direct, quick and decisive while he is described as shy, speculative and passive. The climate for women at the university at this time was such that only men were allowed in the university dining rooms. After work Franklin's colleagues went to male-only pubs.[13]

Despite a tense work environment, Franklin persisted on the DNA project. J. D. Bernal called her X-ray photographs of DNA, "the most beautiful X-ray photographs of any substance ever taken". Her iconic photo of DNA is in all or most biology textbooks. Franklin made marked advances in x-ray diffraction techniques with DNA because only she was able to adjust the equipment to produce an extremely fine beam of x-rays. She had the precision and patience toextract finer DNA fibers than anyone else ever before and arrange them in parallel bundles. She also studied the fibers' reactions to humid conditions. All of these skills, unique to her, allowed her to discover crucial information about DNA's structure.

Between 1951 and 1953 Rosalind Franklin came very close to solving the DNA structure. A photo she took had the key that provided the necessary clue about the double helix. Crick and Watson beat her to publication with a controversial action by Wilkins. Without Franklin's permission, Wilkins showed Watson one of Franklin's crystallographic portraits of DNA. The image gave Watson the missing pieces of information he needed to solve the structure of DNA. [14] The results went into an article in Nature (1953) as quickly as possible because they were conscious of Franklin or Pauling beating them to the credit. Franklin's work appears as a supporting article in the same issue of the journal.

Continued debate about the amount of credit due to Franklin goes on. It is certain that she had a crucial role in figuring out the structure of DNA and that she was a scientist of the highest caliber. Afterwards, Franklin moved to J. D. Bernal's lab at Birkbeck College, where she did work on the tobacco mosaic virus. She also worked on the dangerous polio virus. She was the head ofher own research group at Birkbeck. Upon leaving Randall's lab, she agreed to the condition that she would not work on DNA any further. [15] For a while Franklin returned to her studies of coal. Then, she turned her attention to viruses, publishing seventeen papers in five years. Her research group has the distinction of providing the basic foundation for structural virology.

In 1956, Rosalind Franklin became ill with ovarian cancer. She worked up until two weeks prior to her death less than two years later. She was only thirty seven years old.

Strategies and Activities

I base my lessons on the constructionist approach whenever possible. Constructivism is a style of teaching and learning based on the premise that knowledge cannot be simply given by direct instruction by the teacher at the front of the room to students in their desks. Rather, students learn through active hands on approach that stimulates the mental process to construct knowledge. Students are the builders and creators of meaning and knowledge. Objectives are listed below.

Students will understand:

- The cumulative nature of science
- That the science process generates more questions than answers
- That science has a specific global language of its own
- That scientific research is a long term endeavor
- That long held laws and theories are sometimes thrown out or reworked
- The importance of patterns in science
- That many so called breakthrough of science are often controversial

Activity 1 Socratic Method Puzzle

Objective: Students in a communicative group will make inferences, use deductive reasoning and argument to work together to attempt to justify a conclusion while modeling the Socratic Method.

Lead-in discussion involves the cumulative nature of Science. For instance Mendel studied gene inheritance but he didn't know about DNA. Later, Darwin also didn't know about DNA when he wrote his theory of natural selection that best explains evolution. When the DNA structure was discovered, they did not know yet how it replicated etc.

You will need an intricate image to make a *Puzzle* on heavy paper or glue a interesting image to a file folder about 8"x 10". Cut into puzzle pieces 1"-2" size. You might use a template you have made yourself or you can always use commercial puzzles if you wish. You will need a different puzzle for every 2-4 students. Separate and mix pieces and then place in a large envelope or paper bag. One set for each group. Students will design a record sheet that has four items: puzzle piece number, corresponding thoughts on what the image might be (in the form of a question), percent certainty, and pertinent argument for supporting hypothesis. Students take out one piece placing it on the table for all to examine. For example they would record piece *#1, is it a park scene? 20% certainty, because it has green and brown.* They continue this procedure piece by piece. They may have a run where their data will not vary for several or many pieces. That is ok. They can indicate "ditto". They must discuss their opinions and rational for all changes of their hypothesis so remind them not to rush. They do not have to agree with each other. They continue until they have completed the puzzle. They often get frustrated and misled depending which pieces are drawn in which order. That is a big part of this activity. If you want a bigger challenge remove some random pieces before they start.

Discussion afterwards:

- How does this activity relate to the study of science?
- What specific examples can you give in science where we gained bits of knowledge over time?(fossil record is a classic)
- What did you and your group experience? Frustration? Impatience?
- What kinds of skill did this task involve?
- How often did the members of the group agree? Do scientists work alone when they investigate?

The above activity will take approximately a period of 40-50 minutes. Direct them to do a write up of the activity in their lab book for assessment purposes with these sections: introduction, materials, procedure, data (chart form or other graphic organizer), analysis of data which can be in bullet form (and in this case include the process of going through the activity), and lastly the conclusion which will demonstrates knowledge of the topic: cumulative nature of science knowledge acquisition over history.

Activity 2 Microscope activity

Objective: Students working in pairs will correctly use compound microscopes to view various items on different powers recording detailed observations like Leuwenhoek.

Students will need some familiarity of the basic parts of the microscope and its general use a day or two prior to this activity. Go over focusing procedures again on day of activity. Divide students into random or not so random pairs. For each group of four provide a slide with a magazine image, fabric with a more open weave such as cheese cloth, some newspaper, a ruler with millimeter lines on it and some hair samples. Have students illustrate each type of slide on low, med and high power with a space to record notes too. This may take several periods if you provide all slides mentioned above. With the millimeter rules they can estimate the size of the field of view on the different powers. As an extension challenge they can estimate the width of a hair. A micrometer is a thousandth of a millimeter. Some microscopes have a ruler in the field of view but students can use the millimeter ruler under the scope as a reference. Have students complete a lab report for assessment. Focus on: recording observations carefully, labeling, and awareness of an unseen world made possible by an important tool of science.

Activity 3 Classifying invertebrates with a dichotomous key

Objective: Students in a communicative group will make inferences, use deductive reasoning dichotomous keys to attempt to group invertebrates by investigating preserved specimens.

Much of the scientific study of animals has been done with preserved specimens and still is. Lamarck is known for classifying the invertebrates into the groups we use today. Gather, barrow, or buy ten or more various preserved specimens. Many high schools have large vintage collections. Use *safety precautions* as you would for chemicals. Keep specimens in jars with lids tight instructing students to view through the jar *without* opening! Have appropriate dichotomous keys available to student to use to classify and identify creatures. Alternatives: have students classify creatures based on a system they devise by grouping those with matching characteristics or have students devise a dichotomous key on their own.

Assessment: Student do reports on classification systems in science past and present.

Activity 4 Is it alive?

Objectives: Students will learn that some microbes do anaerobic fermentation.

Prior to this activity discuss cellular respiration and review the characteristics of living things.

Purchase a large amount of active yeast from a discount food supply store. Instruct students that they will have 2-3 mystery samples in petri dishes the next day (dry yeast, brine shrimp eggs, milk powder, and diatomaceous earth). They will design an investigation that would give them information indicating if the specimen was live, dead or non living. Brainstorm possible techniques a least one day prior. Provide various lab-ware for the investigations: safety goggles, stirrers, small beakers, measuring devices, warm, hot and cold water, dissecting scopes, microscopes, iodine, droppers etc. After a day or 1-2 periods of investigations, have students report out to rest of class. Optional demo: mix 1/2 cup yeast, 1/4cup sugar with four cups of warm water in very large bowl with tray underneath to catch spills, stir, observe and discuss. Extension activity: Have student view live yeast under the microscopes at various stages.

My evaluation of their lab report is the formal assessment for this activity. Students must be qualitative and quantitative.

Activity 5 Organic vs. inorganic

Objectives: Students will compare and contrast the pros and cons of buying and eating organic apples vs. apples treated with pesticides.

Preparation for this activity involves brainstorming possible quantitative (mass, density etc) and qualitative measurements (color, patterns, smell etc) and observations that can be made for an apple. Gather 8-10 backyard apples and purchase 8-10 non-organic apples of the same type. Have students compare and contrast. Provide plastic knives so students can cut into the apple. Do not let them eat in the lab. They can do a sanitary taste test back in the classroom that instructor has prepared in a food safe manner. Most or all apples grown without pesticides have worms. It is almost impossible to grow a commercial organic apple without an infestation of the codling moth: apple worm. Students will find holes, waste or actual apple worms inside the treated apples. Now have students do reports on the history and effects of pesticides on human and environmental health. Discuss Rachel Carson's book Silent Spring.

Activity 6 Sequencing with DNA replication

This activity is a casual type of group assessment.

Make a basic sequence chart with the steps of DNA replication. Cut them out in strips, mix the order and paperclip together. Do this for each group. I make 8-10 sets for a class. Have students discuss and work together to place strips in the correct order. They then paste the strips in order on a paper. Encourage participation by all or if that is an issue make more sets, i.e. one for each student.

I think it is important for students to develop investigation questions for all these activities preferably before, but sometimes after is ok too.

Activity 7 alternative assessment

Rewrite of a Song or Poem as an alternative assessment.

Have students write a song or poem based on a familiar one. The rubric must include content, presentations, lyrics, creativity and participation.

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Appendix item A

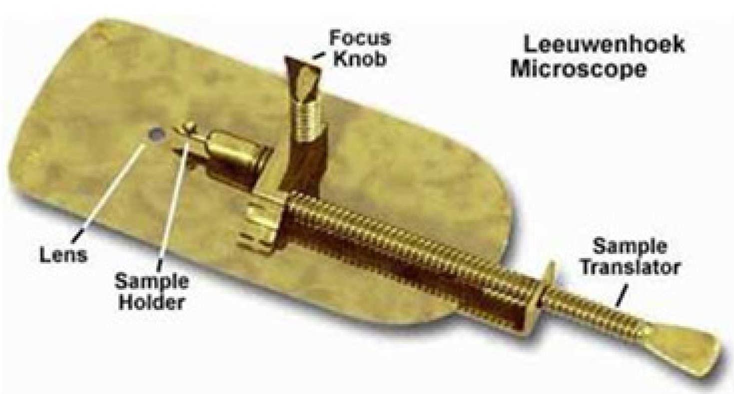
Scientific Method	vs. Socratic Method
1. Ask a question based on prior observations, do research	1. Pose a question to be evaluated
2. *Hypothesis*. Suggest a plausible answer or explanation which is testable	2. *Hypothesis*. Suggest a plausible answer or definition which is hypothetically or virtually testable through argument or discussion
3. Design and perform a controlled experiment. If the experiment fails, restate the hypothesis, otherwise continue.	3. "cross-examination." Perform a *thought* experiment by imagining a case or having a debate.
4. Accept the hypothesis as potentially true. Return to the above step if there are any issues which have not been experimentally confirmed	4. Accept the hypothesis as provisionally true. Return to the above step if there other predictable consequences of the theory which have not been confirmed.
5. Communicate Your Results	5. Act accordingly.

Appendix item B

Strip Sequencing Activity

An enzyme called **DNA gyrase** makes a nick in the double helix and each side separates
An enzyme called **helicase** unwinds the double-stranded DNA
Several small proteins called **single strand binding proteins** (SSB) temporarily bind to each side and keep them separated
An enzyme complex called **DNA polymerase** "walks" down the DNA strands and adds new nucleotides to each strand. The nucleotides pair with the complementary nucleotides on the existing stand (A with T, G with C).
A subunit of the DNA polymerase **proofreads** the new DNA
An enzyme called **DNA ligase** seals up the fragments into one long continuous strand
The new copies **automatically wind up** again

Appendix item C



Appendix D

California State Standards

Experimentation and Investigation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

a. Formulate explanations by using logic and evidence. (Classifying invertebrates Act)

b. Recognize the cumulative nature of scientific evidence. (Puzzle Act)

c. Investigate a science-based societal issue by researching the literature, analyzing data, communicating the findings. (Organic vs. not organic Act)

Genetics

The genetic composition of cells can be altered by incorporation of exogenous DNA

into the cells. As a basis for understanding this concept:

- Students know the general structures and functions of DNA, RNA, and protein. (Strip sequence activity)

- Students know how to apply base-pairing rules to explain precise copying of DNA during semiconservative replication and transcription of information from DNA into mRNA (strip sequence activity).

Endnotes

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