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Data and Graphical Analysis in Life Science

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by Leslie M. L. Solomon

School Profile

Excel Academy is a unique all-girls school in the District of Columbia. The school is a Title 1, educational campus serving students PK3- Grade 8. In 2019, the star rating of the school was a 3 out of 5 stars, however, it was a recent addition to District of Columbia Public Schools. The mission of the school is to "Educate, Empower, and Excel"[1] . The student population is 477, and consists of 99% Black/African American, and 1% Hispanic/Latino/2 or more races. Approximately 10% of the student population is enrolled in 7th grade Life Science.[2]

Much of the data for Excel Academy is not up to date due to being adopted into DCPS in SY 2018-2019. However, there is testing data. In 2019, the number of students meeting and/or exceeding expectations school wide, in science, was less than 5%, compared to DC Overall Science Data of 12.55%.[3] There were no students exceeding expectations. While both are grim numbers, it is clear there is a need for strong, standards-aligned science education. A focus on graph and data interpretation may lend itself in science, social studies, ELA, and mathematics. In 2019, State Standardized Testing was below the district average for ELA and Mathematics, as well.

Rationale

Strong, content-based instruction in graphing and data analysis may help students feel familiarity when encountering these types of questions during DC End of Course Science Testing. Additionally, students should show gains in ELA, Math, and Social Studies Testing – as these sources also cite data, reference text(s), and explain rationale. Strong foundations in data and graphical analysis will lead to future success in science in other secondary courses. In a time when numbers and figures are presented routinely in news and social media in charts, graphs, and diagrams, this unit will help increase science literacy and being able to determine flaws in data presentation. "It is imperative that we integrate teaching visual literacy in our classrooms so that our students can understand – and value – technical images.[4] " *NGSS For All Students* explains that every student needs science to encourage a data literate population, to prepare for career

readiness regardless of career choice, and to attract students to science[5] . I agree.

It is also key that science education builds upon physical, historical, or sociocultural information to be effective for students who are economically disadvantaged. The economically disadvantaged continue to show larger and large achievement gaps in science[6] . When analyzed according to race, there are still deficits in the numbers of Black and Hispanic workers in STEM.[7] When we focus on students from racial and ethnic groups, the lack of inclusion can be reduced with "1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representation and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds.[8] " Excel Academy features items #2-4. However, a further emphasis is needed on item #1 – *Culturally Relevant Pedagogy.*

A disproportionate number of girls choose careers unrelated to STEM. While women are 48% of the workforce, they are only 27% of the STEM workforce[9] . Research suggests that there are three ways by which we can encourage girls to pursue these areas; instructional methods, decisions in content, and classroom/school setup. The goal is to increase exposure of all areas of science to young females and to reduce the "experience gap.[10] " As graphs are a common theme throughout all science topics, I would argue it is the first step to enhance familiarity with scientific concepts.

Background

Claim-Evidence-Reasoning to Justify Claims

Bobrowsky proposes several criteria to teaching solid science, and not perpetuating the archaic "scientific method.[11] " First, he proposes that teaching methods should mirror real-world science investigations. Second, they should inspire student interest and enthusiasm, and thirdly, it should be supported by current science pedagogical research.[12] One of the best ways to do this is the use of the CER (Claims-Evidence-Reasoning)[13] . See examples under "Engaging in Arguments" for how graphing can be utilized to inspire a Claim-Evidence-Reasoning response.

There is a misconception that students should "prove" their topic sentences, when in fact the protocol in science is to lend support-for or -against a claim. He recommends, "emphasizing to students that defending claims at all costs is not about science is about. Scientists are open to new ideas and even welcome being shown they are mistaken, because that's when knowledge increases and science advances.[14] " This may include backing up a portion of scientific knowledge – "describing relevant evidence" but also in creating an appropriate claim[15] . Such tasks can be made into activities and can be used to show a connection between writing in the sciences and other areas. All Activities can be amplified to include supporting a claim with evidence and reasoning. This is an extension or requirement that will be seen throughout and can be applied to even activities not found under Teacher Resources.

Analysis of Collected Data

Data collection is essential in the pedagogy of scientific inquiry. However, it is not enough to simply collect the data. It must be debriefed. Ashbrook suggests that a scientific discussion of data can occur even in early

childhood interactions.[16] She suggests conversations with small groups (or even the entire class) asking for key ideas, patterns, and new queries. The goal is also to have students articulate their ideas in writing or verbally. Perhaps even in older students, who have not been trained to look at scientific data at an early age, a similar process must occur to develop their skill in a guided fashion before it can be expected independently in assignments and/or state science testing. Doto and Golbeck have students collect data in the form of photographs for elementary aged students.[17] The collection of data is a rather lengthy process. Therefore, for multiple exposures within a unit, some data may be collected, while others may be presented.[18]

Peer Data Analysis Critique

When students enter the science classroom, they have various levels of science and mathematics readiness and skill.[19] Clary and Wandersee recognized that although they used published data and also student generated data, students "needed additional practice in generating and interpreting data.[20] " Their students favored multiple choice questions, so they needed a process to teach students graphical creating and analysis skills. They utilized Microsoft Excel and a Random Number Generator to create individual data sets. After experiencing a hands-on fossil activity, students received their unique sets of data. On the next class, they received a peer's data set and analysis. The goal was to submit an evaluation of their peer two days later.

According to Clary and Wandersee, high school students exceled at the assignments and thought it was personally relevant. Students gave positive feedback to their peers, and ownership of each data set was taken. Teachers allowed them to give anonymous feedback. Overall, this technique seemed valuable and beneficial for students and teachers[21] . Ostroff suggests that classroom dialogue helps students with learning and cognition.[22] Participation in discussions can utilize all the cognitive functions and improve student performance. "Dialogue is one of the few pedagogies that truly empowers and transforms learners."[23] Discussions help not simply cognition, but also the building of community.

Deeper Dive into Discussions

It is important to consider whether discussions will be graded, and if that grade will be individualized. Grading can create accountability. However, individual accountability can change how discussions occur in the community science environment. Wiggins suggests a group grade for discussions. She recommends a "symbolic grade," so that individual grades are not unfairly weighted. However, she utilizes a spider web discussion model, which encourages asking dynamic questions and directing the group back to the text. Speaking and listening more is also encouraged.[24] Discussion is key to facilitating the key places students should look, before they develop their own self talk. As all the Teaching Activities feature data, discussions can be implemented in a small group fashion to help coach students. Activity #4 has students collecting their own data, as well.

Generating and Answering Student Questions about Data

Moore and Huber have another process to determine "productive questions" for data analysis in middle school classrooms.[25] Students can create their own or they can use resources in the classroom to generate answers – such as textbook or specially chosen articles. However, in their method, students must be taught how to manipulate spreadsheets – which may prove challenging for students with technology or cognitive challenges. Perhaps these students can be given data with less difficulty or complexity as a modification to their learning process.

Another possibility is having students graphing their ideas in advance of the collection of data, such as in the Connery's article.[26] Connery states that students can collect data, but do not really have an understanding about what the line on the graph means, without intervention. Connery states that graphing in advance of collecting data is extremely beneficial when the goal of the lab is to figure out what the relationship is between two variables.[27] This lends itself very well to the physical sciences. However, determining the independent and dependent variables of an activity, and even a working hypothesis, may be very useful in the 7th grade Life Science in preparation for the physical sciences in the 8th grade.

The clarification of when to use a bar, line, pie, or scatterplot should be utilized before diving into the first learning activity, but AFTER the *Pre-Assessmen*t. There should also be some discussion of independent variable, dependent variables, direct relationships, and inverse relationships. These are easy topics to review, integrating into a warm up or exit ticket throughout the course.

The Nature of Science and Data Analysis

Science has been traditionally introduced using "The Scientific Method." However, there is no one Scientific Method. Many pieces of scientific knowledge could not be acquired by conducting an experiment (ie: stars moving toward or away from earth), nor is it feasible that all data is collected planned (ie: the effects of a drug on human fetuses). Although, quite common – it is ineffective for teaching experimental design.[28] It is through experimentation and research discussions that opportunities to learn experimental design are amplified. Explicitly teaching how to analyze data is imperative.

Unit Overview

First, the unit *Pre-Assessment* should be given. Students should be asked to do their best. It should be expected that students will have questions and concerns, however, resist the urge to explain the content and information. Only reiterate and rephrase instructions as necessary.

Prior to beginning of the first activity, the acronym "DRY MIX" will be introduced. to help students to determine the dependent-responding (variable) is on the y-axis. Whereas the manipulated -independent (variable) can be found on the x-axis. Time is a general exception to this rule. This portion of the instruction can be amplified to include activities that present scenarios, to identify the independent variable vs. the dependent variable. This will evolve to the presentation of graphs to get a similar type of response. This will graduate to will include completed graphs and the phrasing "Science Graphs have TAILSS, to stand for Title, Axes, Intervals, Labels, Scale, and Summary. Please see the image below for an example.

These strategies have been used effectively the last 15 years of science teaching to teach and streamline graph fundamentals. It was created in conjunction with *Students and Research.*[29]The next step is to will teach how to use the cite the data to create a Summary, as indicated in T.A.I.L.S.S. A suggestion here is to use multiple sources of data, randomly generated, to create a peer system of graph evaluation. Subsequent Sections will proceed with relevant data from each content objective and/or activities. Data will increase in complexity and will present opportunities to culminate in a Claim-Evidence-Reasoning Prompt. An example of the attributes of T.A.I.L.S.S. can be seen at the bottom of Figure 4. An example of a Pre-Assessment that may be used. A similar Post-Assessment can be utilized.

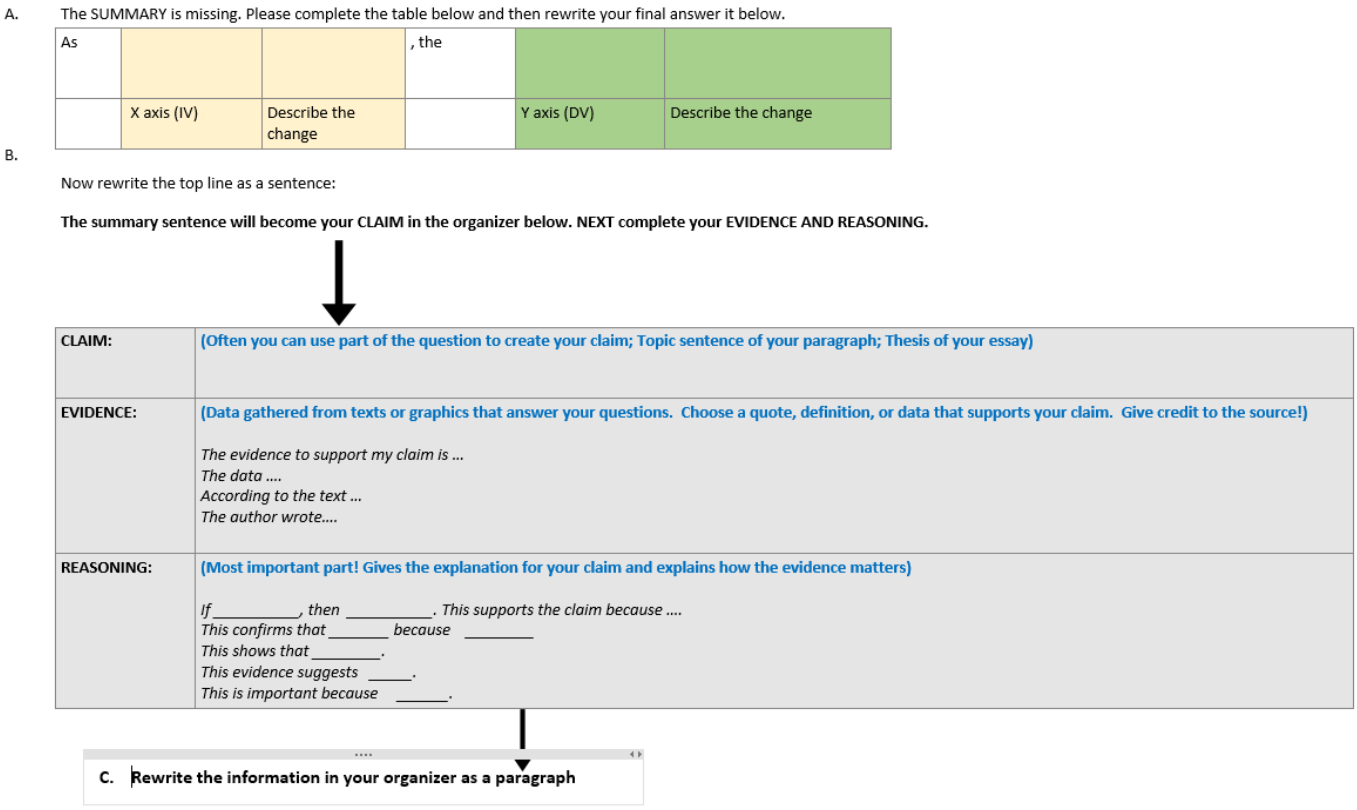

Figure 2 Common Graph to CER Paragraph Walkthrough

Content Objectives

Next Generation Science Standard (NGSS) Standard Integration

The unit will incorporate standards from the Next Generation Science Standards (NGSS) for each unit throughout the year. Every student needs to learn science The National Research Council convened for several years to formulate these standards with the goal being that the information presented to students included quality content for all students, be based on science, concise, address the needs of different states and socioeconomic statuses.[30] In addition, the science content needed to align with the *Common Core State Standards*, be a progression across grade levels and address the needs of students based on research.[31] I feel strongly that these requirements unify and standardize science the best, while allowing states the freedom for individual state adoption.

Unit – Lesson Construction and the 5E Instructional Model

Within NGSS, Bybee explains the 5E Instructional Model.[32] Each "unit" of content is broken up into multiple lessons, that may a part or whole class period. It may even extend into the next class. The Engage portion of the cycle typically present a phenomenon or other activity that can allows the ability to capture the student's interest, but also gauge prior knowledge and misconceptions. It is suggested to ask a question that has students enter "curiosity, anticipation, and challenge" to prepare them for learning.[33] The Explore portion

allows a common experience to base future lesson while allowing them to have a hands-on / minds-on discourse. During the Explanation (also known as Explain) phase students develop explanations. Their ideas from earlier moments are clarified and misconceptions are rectified. Elaboration allows students to apply new understandings to a new context. Evaluation seeks to assess students on grade level expectations. Graphing can be invoked at any step along the 5E Model.

These activities are probably best utilized as Engage or Elaborate portions of the 5E cycle. They cannot be used alone as Explain, as the key content pieces would probably need to already be introduced.

POE (Predict, Observe, Explain) Instructional Model

This model correlations with the Explore phase of the 5E model[34] . Students first predict what they *think* they will see. Students then observe and collect qualitative or quantitative data. Next, they use what they saw, however, they must use what they observed as their evidence. This model mirrors Peer Analysis Critique Model presented earlier. This will be utilized for graphing activities within the unit. The chart below can be utilized for any demonstration or prediction of data prior to showing students the chart and/or graph results. It can be used to drive discussions about key points and misconceptions.

Next Generation Science Standard (NGSS) Disciplinary Core Ideas

Structure and Function

The Structure and Function component focuses on how organisms "grow, reproduce, and die.[35] " The idea is that organisms are made of cells. Organisms can be multicellular or unicellular. In multicellular organisms, a group of cells works together to provide a specific function. In unicellular organisms, organelles complete a similar task with less efficiency. In my school, life science contains all the goals for this course grades 6-8. By the end of Grade 8, students should know that all living things are made of cells, the differentiation between unicellular and multicellular organisms, which select special structures provide specific functions at the unicellular and multicellular level, and the function of select body systems. This information builds on Grade 5 knowledge, which focuses on the differences between plant and animal internal and external parts.[36] Two years is a long gap without review, so often this information must be retaught.

Information Processing

Being able to perceive and react to the world around you is what increases survivability at the organism and species level. Each animal has different types of receptors internally and externally and each responds to a different type of information.[37] By the end of Grade 8 students should know the different types of information (electromagnetic, mechanical, chemical) and how they are transmitted. There is also a discussion of memories and how they are aggregated over time.[38] This topic may be folded into Structure and Information Processing and/or Growth and Development. It also can be utilized in conjunction with Structure and Function, as your district allows.

In preparation for *Unit Activity #2*, the preassessment (*Unit Activity #1*) should be complete. In addition, teachers may find an introductory activity such as a M&M graphing Lab or the Graphing Skills Gizmo useful, to review fundamental concepts of line vs. bar graphs. This lesson should take approximately one class. Students should also know the basic organelles of a cell including, mitochondria. '*Which types of cells would have the most mitochondria" could be an excellent warm up question or POE task* (5 minutes). Depending on a student response, a review of what the mitochondria does within the cell may be necessary (5 minutes).

After a generous discussion, have students complete the graph and questions. They should be able to illustrate a bar graph with proper T.A.I.L.S.S (20 minutes). A gallery walk may be useful for Peer-Critique-Review (10 minutes). They should then formulate a CER to support their answer utilizing Figure 2 Common Graph to CER Paragraph Walkthrough Figure 2 Common Graph to CER Paragraph Walkthrough Figure 2 Common Graph to CER Paragraph Walkthrough. Encourage students who want to know "why" to research and propose some ideas. This is an excellent way to differentiate the class for students who finish early. They may revise their reasoning to include this new information. This writing portion may take 15 to 30 minutes depending on writing ability of your students.

Growth and Development of Organisms

Fundamentally, the parts of an organism and how they function changes with maturity – from birth to old age. It is important to understand that animals have behaviors that increase reproductive possibility and viability, and plants depend on the growth of special structures and/or animal involvement for the same. By the end of Grade 5, students understand that plans and animals are different, but both grow and reproduce. However at the end of Grade 8, students are to understand the difference between sexual and asexual reproduction. The focus is on plants, however, in discussion of specialized reproductive features, how plants continue to grow due to photosynthesis, and that genetic and environmental factors make a difference. Animal growth is affected by genetic factors, food intake, and interactions with other organisms via the food web and/or special relationships.[39]

Going Viral is a technology-based activity that shows the spread of viruses.[40] This activity features a simulation and a creation of an infographic to explain living and non-living organisms, but also a look at global spread. The current COVID-19 pandemic offers the perfect opportunity to look at this data utilizing the CDC Website. Formative assessments are used to gauge misconceptions and the building of new knowledge in our students. In addition, *Unit Activity #3* provides another opportunity to look at Asexual Reproduction of Mold.

The Going Viral simulation can be utilized in a variety of forms. A comparison of viral prevalence in October of 2020 vs October of 2021 can be presented to students. Students can be asked about observations of the graphs as a warm up (5 minutes). A discussion of why a line graph is a better representation of the trend data for these two years is important, especially in comparison to Activity #2. Another possibility is having students draw what they believe the graph looked like for each of these points. For this, white boards may be useful. The choice is based on the graphing ability of your students. At this point, Activity #3 can be introduced.

Unit Activity #3 presents data from the lab, charting the speed at which mold is growing in a sample taken from an apartment in Ward 8, Washington DC. The student should graph the data, and then use evidence in the two articles provided to explain why the mold is potentially dangerous, in CER format. Students will first need to graph the data with T.A.I.L.S.S (15 min), and then take the summary into a CER Writing Prompt (15 minutes.) Students experience the greatest challenge citing data from the graph and utilizing text sources as a reasoning as to why the mold is bad for residents. At times of 0 to 5 hours, the black mold counts were 10, 70. 135, 180, 250, and 320 respectively.

Inheritance of Traits

At the end of Grade 5, it is known that genetic differences are passed down from parents. However, by the end of Grade 8, genes and chromosomes are discussed in detail. Students learn that there are two variants of each gene inherited. This relates back to sexual and asexual reproduction discussed earlier. A distinction is made in asexual reproduction in which both the parent and daughter cells/organisms are genetically identical.

Whereas sexual reproduction results in offspring inheriting genes from each parent, creating an all-new combination of genes. The mechanism of how genes are passed down is not discussed, only the impact of the process and the rare changes from mutations.[41]

Variation of Traits

The variation of traits focuses on the effect of when inherited traits differ and how that affects how animals look, function, and behave. In Grade 5 students learn what traits are and that there are multiple versions of the same trait (a brown dog vs a black dog). By the end of Grade 8, we focus on the idea that two genes are donated, and that the genes may be identical or different. Mutations are also discussed as possible changes that change the structure and function of proteins. As a result, an organism may encounter benefits, harm, or be unfazed by the genetic difference.

Activity #4 is a Trait Inventory and many versions of this can be found online. As a warm up, students should first be asked which of their traits they believe are genetic. Students will often pick items that are a blend of environmental and genetic factors (5 minutes). This would be a good time to review relevant vocabulary. Next students should evaluate themselves for whether they have dimples, attached earlobes, the color of their eyes, the presence of freckles and their hair color. They also can evaluate whether they naturally clasp their hands left over right or right over left. After making these observations, they should guess whether these traits are dominant or recessive.

Using a class tally, students can calculate the number of students in their class with each of these characteristics. It would be helpful to choose one with variety so they can see how the calculation is done. Example: # of students with trait / # students in class 100 = _____% in Class (20 minutes). Students can then answer the following 2 questions: 1. Which do you think happens more often, a dominant trait or a recessive trait?, and 2. Use the list of Dominant and Recessive Characteristics from your teacher. Find an example of a recessive gene being more common than a dominant one and explain why you think it may be more common.

This discussion helps to lend itself to a discussion of Eurocentric views of beauty. Many of the characteristics we deem attractive as a western society are recessive traits; such as light eyes and hair. Others, we place no value on (such as hand clasp). In a female-centric school, it is important to take this time to address self-value and how each of us our unique combination of dominant and recessive traits. Also that, despite having identical parents, we can look very different. This reflects the uniqueness of each individual 30 minutes). A wonderful closing activity may be to have students discuss three features and how they feel about them after discussing their dominance and recessive nature genetically.

Organization for Matter and Energy Flow in Organisms

Life requires both energy and matter to be perpetuated.[42] This particular topic overlaps carefully with the prior two topics, as well as Interdependence of Organisms. The idea is that energy from light is harnessed by plants, algae, and other microorganisms to create sugar. Animals consume these organisms (or other organisms that eat them) to make new molecules, to make energy, or to release. Ultimately, other organisms use chemical processes to return this energy back to the environment.[43] There are no graphing activities in this Unit to support this Disciplinary Core Idea, however, data from a Gizmo or other lab can easily be adopted into a CER format for practice.

Interdependent Relationships in Organisms

There are several of these concepts that overlap and folder into the others. This is true of the next few topics. This particular concept looks at how matter and energy interact with biotic and abiotic factors in the environment.[44] At the end of the Grade 5 students understand how food webs work and how ever animal can be traced back to plants. Also, how organisms can only survive and reproduce where their needs are met. At the end of Grade 8, populations, resources, and their interactions are added. In addition, competitive, predatory, and mutually beneficial connections are explored.[45] The use of food webs and diagrams can be utilized with POE, discussions, and CER evaluations to continue to move this idea forward. This will assist will understanding C*ycles of Matter and Energy Transfer in Ecosystems*, *Ecosystem Dynamics, Functioning, and Resilience*

and are prerequisites to the completing of *Unit Activity #6.*

Cycles of Matter and Energy Transfer in Ecosystems

Food webs, interdependence, and organization for matter and energy flow interact in this current topic. The focus here is specifically how they interact within an ecosystem.[46] At the end of Grade 5 students understand how the needs are provided and cycled between air and land for animals, plants, and microscopic life. By the end of the Grade 8 the focus moves to how consumers, producers, and decomposers return the molecules themselves back to create a cycle. In fact, this section focus on each's individual role within the cycle.[47] Food webs and other diagrams can also be used here to further explain concepts. These are also prerequisites to the completing of *Unit Activity #6.*

Ecosystem Dynamics, Functioning, and Resilience

"What happens to ecosystems when the environment changes?"[48] In Grade 5 the focus is on temperature and availability of resources, or migrations. In Grade 8 the focus shifts to physical and biological components of the ecosystems that extend beyond the Grade 5 concepts. Biodiversity is also discussed as the variety of species in the environment and how we use this information to judge the health of the earth.[49]

By analyzing the relationship between race and environmental health, students can be engaged in *Ecosystem Dynamics, Functioning, and Resilience* while developing a personal connection to the material.[50] Students begin engagement by looking at images, artwork, and/or graphs about environmental racism in their areas. After building background knowledge, students receive case studies, create journalistic style articles to report on findings. This activity could be used as is, provided that local data has been pulled.

Social Interactions and Group Behavior

The fluidity and stability of social groups is the focus of this topic. Living in groups increases the likelihood of survival. In Grade 5 the members of a group are described and defined. Some members provide the same functions, whereas others have different ones.[51] In Grade 8 the focus changes to why groups dissolved, because the group doesn't mean the individual's needs, social structures fall apart, or if death and isolation occur.

Evidence of Common Ancestry

At the end of Grade 5 students should understand that fossils provide information regarding the types of

organisms that lived and what their environments were like. In Grade 8, it is explained that they are mineral replacements, remains, or traces of past organisms. The collection of fossils is in reverse order from how things happen. It helps us to understand what was once alive, how it has changed, and where exactly different organisms lived throughout history.

By observing fossils we can see the differences and similarities between past organisms and those living in the present. In this way, evolutionary history and the theory of a common ancestor can be reconstructed. This is even more evident in embryological development across species.[52]

Twenty years ago, it was not uncommon to see the Anacostia River, which flows through Ward 8, filled with trash, food wrappers, and other filth. The number of blue crab, oysters, osprey, bald eagles and many other animals dropped in the Chesapeake Bay area, to include the Anacostia. One such animal we will focus on ins the Osprey, a native bird. There are only 100,000 of these birds worldwide, and 1/5 of that population resides in our area. They are a common sight at Anacostia River Park. As such, *Unit Activity # 6* deals with this abundance of this animal over the years. Students will read a short pdf of a poster, look at the data, and create a Claim, Evidence, Reasoning prompt to support/refute a claim given by a student.

Natural Selection

Because the variation of genes within a species can be positive, negative, or neutral, a particular organism may benefit or suffer from such a change. It may affect the ability to survive. In Grade 5 students learn this may influence who and what can reproduce. By the end of Grade 8, students learn there is both natural selection and artificial selection. Artificial selection is when a particular organism and/or set of traits is favored by humans. Natural Selection leads directly into understanding Adaptation.

Adaptation

When there is a change in the environment, resources available may change. As a result of change, a preference for a specific set of traits is formed. The environment influences the distribution of traits over time.[53] At the end of Grade 5 students only need to know that sometimes the changes in the environment may be beneficial or harmful, resulting in some organisms surviving or dying. The Grade 8 goal includes looking at these adaptations as they will affect over many generations. The idea that common traits are favored by the environment whereas less common traits are not encouraged by the environment. When a population is separated, those changes can become so broad a new species can develop.[54]

Unit Activity #5 Seeks to look at the mean beak depth of a group of animals before and after a drought. Students can graph this data and then explain how it affected the offspring. It will also help them to see how the adaptation helped some to survive, and to explain that concept in CER format. An additional activity was one that explained the connection between Sickle Cell and Malaria. Sickle Cell is an example used to explain several concepts (mutations, protein synthesis, heritability). It is a wonderful ongoing trend, as many of my students know someone with the disease or trait. However, this activity could not be modified without using the worksheet in its entirety. Consider using it as a reinforcement.

Activity #5 Could be started by a discussion of how our eating habits would change over generations if all *meat* sources were eliminated. *How would human bodies change?* Students should consider what is necessary to process and eat meat biologically, but also the benefits meat gives us. How would our future generations change? At this point they can be presented with the data from the finches on the Galapagos

Islands. As this is the 5th activity, students should be challenged to process the data and answer the questions independently (20 minutes), process a CER paragraph (15 minutes) and perhaps do a peer review (15 minutes). Students on the next class can be given a few exemplars (high, low, medium – but unmarked). Student names should be hidden. Students should be asked to find the score the graph, but also to find and score the claim, evidence, and reasoning statement. I find highlighting each characteristic in a different color very useful here. Activity #6 can follow a similar format, however, it adds the challenge the students muse find the data within the reading itself.

Next Generation Science Standard (NGSS) Science and Engineering Practices

Analyzing and Interpreting Data

While students are able to collect data at an early age, it doesn't automatically come with an organizational system for analysis. That has to be directly taught and/or scaffolded.[55] Students have to be taught how to interpret a chart or graph (interpolation), but also predict what may happen next (extrapolation). "It is important for teachers to understand what sorts of visual representations of data are going to be effective for different age groups.[56] "

The challenges in graphing vs interpreting graphs shows the challenges within completing a procedure vs. understanding the core concepts behind it.[57] It is common for students to give a literally explanation of a graph that illustrates a lack of fundamental understanding of the process at hand. There are times that students will interpret the meaning of a graph without actually even considering the scales on either axis. In addition, students need to be taught clearly the differences between observation and inference and how to measure whether data is valid.

By the end of Grade 8, students need to be a be to create, analyze, and explain graphs.[58] They should also be able to use charts, maps, tables, and other visuals to explain trends in large sets of data. Students should be able to determine the difference between correlation and causation. Also, they should be able to use the graph as evidence of this. The use of mean, median, mode, and digital tools should be applied. Being able to improve accuracy and precision with repeated trials or using technology to create graphs, is a a part of reducing error. They should also be able to use a graph to figure out the "best" situation to operate under.

Students can gain visual literacy skills by observing graphs, models, and maps.[59] In *Under the Sea,* students engaged in the ecological effects of the Deepwater Horizon oil spill on the ocean. A similar activity can be modeled using the Chesapeake and /or Washington DC Reservoir. Students analyzed images, studied coral communities, looked at the health of those communities, and created graphs through the use of coding each type of coral.[60]

Using Mathematics and Computational Thinking

It is impossible to use data without using math. They are symbiotic.[61] Students should be able to use ratio, but also the statistical ideas of median, mode, and mean. This can be further to extrapolated to a move from subjective measures (like warm and/or cool), to more quantitative measures (like using numerical temperatures). Also understanding graphs as a form of a visual representation of numbers in terms of slope. Being able to take measurements is also important.

Being able to digital tools to analyze measurements to analyze data is a skill to learn by the end of Grade 8.

In additions, students should utilize math to support a rationale for scientific concepts and information. They should be able to utilize a set of steps to calculate answers, and use simple algebra and rations. They should also be able to use digital tools to test to see if their explanation holds.[62] *Unit Activity #4* explicitly asks for calculations and comparisons; however, they can be added throughout other activities.

Constructing Explanations and Design Solutions

One of the major goals of science is to explain the world by creating theories. As teachers, our job is to help our students make individual sense of how the knowledge is used.[63] This connects back to the idea of the "Engage" and "Explore" common experiences, to lead to "Explanations."

Students should be able to use qualitative and/or quantitative data to develop an explanation, as well as utilize models for the same. They should create this explanation utilizing valid evidence but use scientific ideas to revise and reconstruct the claim as new evidence is acquired. The application of reasoning to support the claim is also necessary. Additionally, students should be able to evaluate, edit, and synthesize a current system provide evidence of their explanation.[64] This is the purpose of the Reasoning portion of the CER.

Engaging in Argument From Evidence

It is extremely important that students speak in the classroom and use language to help them develop concepts. CER is one way. Another is Initiate, Respond, Evaluation (IRE) Method. In this method, a teacher poses a question, then students respond. In the last step, the teacher evaluates the response. The failure in this method is overreliance on the teacher to vet the authenticity of the response.[65] It is important the norming of practices of for scientific argumentation are implemented. As student continue the argumentation process, their understanding of concepts are strengthened individually.

Students should be able to compare and critique two arguments with similar claims, evidence or reasoning. In addition, they should be able to give critique to themselves. They should be able to present an argument orally and/or in writing and evaluate other design solutions presented.[66] "…merely uncovering students' alternative ideas is not enough. Students must be confronted with them and guided through a sense-making process that gives them the new evidence they need to willingly give up or revise their alternative ideas when they realize that these ideas no longer who explanatory power.[67] " This seems to mirror the ideas of Bybee and the fundamental concepts of the 5E Instructional Model.[68]

Appendix on Implementing District Standards

Next Generation Science Standard (NGSS) Standard Integration

DCPS Unit 1 - LS1: From Molecules to Organisms: Structures and Processes *LS1.A: Structure and Function*

DCPS Unit 2 - Growth and Development of Organisms *LS1.B: Growth and Development of OrganismsLS1.C: Organization for Matter and Energy Flow in OrganismsLS1.D: Information Processing*

DCPS Unit 3 - LS3: Heredity: Inheritance and Variation of Traits *LS3.A: Inheritance of TraitsLS3.B: Variation of Traits*

DCPS Unit 4 - LS4: Evidence of Common Ancestry and Diversity *LS4.A: Evidence of Common Ancestry and Diversity*

DCPS Unit 5 - Changes in Organisms Over Time *LS4.B: Natural SelectionLS4.C: Adaptation*

DCPS Unit 6 - Ecosystems: Interactions, Energy, and DynamicsLS2.A: Interdependent Relationships in EcosystemsLS2.B: Cycles of Matter and Energy Transfer in EcosystemsLS2.C: Ecosystem Dynamics, Functioning, and ResilienceLS2.D: Social Interactions and Group BehaviorLS4.D: Biodiversity and Humans

NGSS Science & Engineering Practices

There are 8 Science & Engineering Practices for NGSS. NGSS SEP #1-3 will not be explicitly utilized. It is the goal to include these into the Graphical Analysis Unit:

4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

NGSS Crosscutting Concepts

There are 7 Cross Cutting Concepts for NGSS. It is my goal to incorporate these into the Graphical Analysis Unit:

1. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

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Teaching Resources

Activity #1 PreAssessment

Graphing Concept Check #1 Version A

Ethylene is a plant hormone that causes fruit to mature. The data above concerns the amount of time it takes for fruit to mature from the time of the first application of ethylene by spraying a field of trees.

Amount of methylene in m/m^2	Apple A
10	14
15	12
20	11
25	10
30	8
35	8

1. What kind of graph is best to show this information

2. What is the dependent variable?

3. What is the independent variable?

Create the graph on the sheet of graph paper. Be sure to use TAILSS. Check the rubric below to see how you will be graded.

Title	4	3	2	1	Relates the independent and dependent variable. Includes units where appropriate.
Axes	4	3	2	1	Has the independent variable on the correct axis Has the dependent variable on the correct axis
Interval	4	3	2	1	Has proper spacing that uses the entire axis. Graph starts at 0.
Label	4	3	2	1	Has labeled the graph's axes correctly with units
Scale	4	3	2	1	Uses the majority (50% or greater) of the graphing space.
Summary	4	3	2	1	Summarizes the trends of the graph using 1-2 sentences. The summary is thorough and completely accurate

Explain your findings in a paragraph. Use your summary as your topic sentence or CLAIM. Support your CLAIM, with EVIDENCE and REASONING.

Figure 3 An example of a Pre-Assessment that may be used. A similar Post-Assessment can be utilized.

Suggested Activity: Introduction to Science

For this unit, The Graphing Skills Gizmo at www.explorelearning.com is highly recommended. The activity has students create different types of graphs. In this process students choose the type of graph (bar, line, pie, or

scatterplot), and then get to adjust the graph to check its accuracy. This activity is a paid service from my district and has activity worksheet to go along with the online service.

Activity #2

DCPS Unit 1 - LS1: From Molecules to Organisms: Structures and Processes

LS1.A: Structure and Function

Number of Mitochondria Per Cell	
Fat Cell	100
Liver Cell	2500
Muscle Cell	1200
Red blood cell	0
Skin cell	200
White blood cell	700

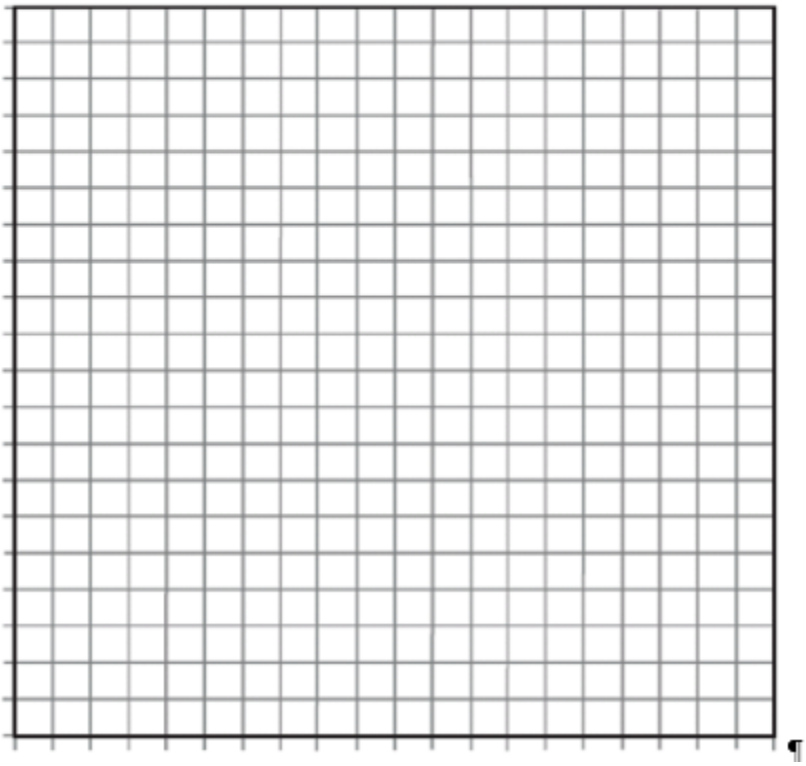

Figure 4 Number of Mitochondria Per Cell Taken from: Phelan, Jay. What Is Life?: A Guide to Biology. New York, NY: W.H. Freeman and Co., 2013.

Use the data above to answer the following question: *Which type of cell has the most mitochondria?* Support your CLAIM, with EVIDENCE and REASONING.

***Activity # 3*- Growth and Development of Organisms**

LS1.B: Growth and Development of Organisms

Readings To Support:

- Mayhew, Elizabeth. “Mold Is an Expensive and Dangerous Problem. Here's How to Get Ahead of It.” The Washington Post. WP Company, September 1, 2020. https://www.washingtonpost.com/lifestyle/home/mold-is-an-expensive-and-dangerous-problem-heres-how-to-get-ahead-of-it/2020/08/31/52900efe-e6d3-11ea-97e0-94d2e46e759b_story.html.
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***Activity #4* - LS3: Heredity: Inheritance and Variation of Traits**

LS3.A: Inheritance of Traits and LS3.B: Variation of Traits

Suggested Activity: Evidence of Common Ancestry and Diversity

LS4.A: Evidence of Common Ancestry and Diversity

For this unit, The Human Evolution Gizmo at www.explorelearning.com is highly recommended. The students will compare the holes within skulls of various human ancestors. They will be able to ascertain which were bipedal (standing on two feet), and which are the closest ancestors to humans. Worksheets are available online via our subscription service.

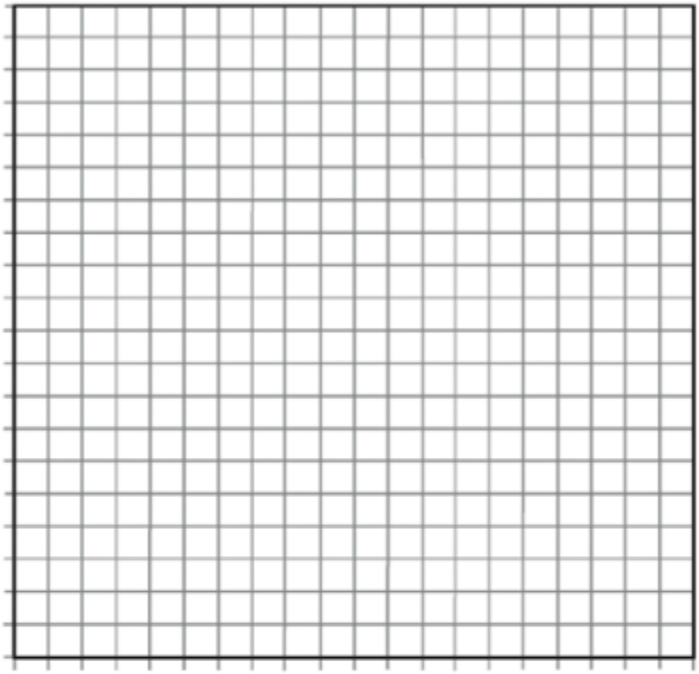
***Activity* #5 - Changes in Organisms Over Time**

LS4.B: Natural Selection and LS4.C: Adaptation

Part 1: Scientist were curious about whether the size of the beak was genetically linked. They measured a group of parents and the beaks of their full-grown offspring. See the data below.

Beak depth in finch parents and their offspring

Mean beak depth (mm)	
Parents	*Offspring*
9.3	*9.1*
10.3	*9.5*
9.7	*8.9*
8.1	*7.7*
9.9	*9.5*
8.4	*8.8*
10.2	*9.8*
8.4	*8.3*
8.8	*8.6*
10.0	*10.2*



1. *Determine your Independent Variable (x) and Dependent Variable (y) Tip: Does the parent's beak affect the offspring? OR Does the offspring beak affect the parents?*

2. *Create a scatterplot, do not forget T.A.I.L.S.S.*

3. *Are the two variables related? If so, draw a scatterplot.*

4. *Does the data support evidence that beak depth is genetically linked?*

Part 2: A major drought killed of most of the native finches' food source. Many died because they could not crack the seeds of the plants remaining. Before the drought, the average beak size was 9.2 mm. However, in the year after the drought the next generation had a beak size of 9.7 mm. How did natural selection act on the finches to give them an advantage? Explain in claim, evidence, reasoning format.

Figure 5 An example of data utilized for wildlife to reflect adaptation and natural selection.

Activity # 6 - Ecosystems: Interactions, Energy, and Dynamics

The following information was taken from: Ospeys at Jug Bay *at https://www.pgparks.com/DocumentCenter/View/11444/Ospreys-at-Jug-Bay-poster-PDF*

1. *Based on the article, how did the Osprey population drop drastically?*
2. *After the 1972 ban in the United States, how did the Patuxent River Park try to help increase the Osprey population.*

3. *Use the graph, within the poster, to support/refute a claim that "Nesting Towers did not help to increase the Osprey Population.". Be sure to use and EVIDENCE, REASONING Format to support your CLAIM.*

Notes

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[42]*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, pg 147

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