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Curriculum Units by Fellows of the National Initiative
2026 Volume VI: Asking Questions in Biology

Dermatoglyphics (Fingerprints), the Data Cycle, and Asking Questions

Curriculum Unit 26.06.07, published September 2026
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Demographics

The curriculum unit is designed for fourth grade students in Richmond, Virginia. I teach in a state which does not follow Common Core standards but instead uses the Virginia Standards of Learning. My school, Mary Munford Elementary School, is in the west end of the city of Richmond, Virginia. It is a part of Richmond Public Schools. The students mostly come from middle-class homes with a lot of parental support, but there are also immigrants, students from low-income homes and a few homeless families. My school also serves low-incidence autistic students. The range of skill level in fourth grade is huge. A few students barely speak English, some perform two years below grade-level, and other students perform in the 99th percentile on norm-referenced tests for reading and math. My students' general knowledge also varies greatly. Some students read constantly and have opportunities to travel around the United States and to other countries, while others rarely leave Richmond.

Introduction

Fingerprints have fascinated people for thousands of years! They have been depicted in prehistoric cave art and used as unique identifiers in ancient Babylon. Despite the long history with fingerprints, many answers about them seem to be elusive. Why do humans have them? How do they form? Why are they unique to every human being? I was surprised that my research did not yield the answers I sought. The more research I conducted, the more questions I had. I could not have predicted that fingerprints would be the perfect topic for a unit designed to teach students how scientists ask questions to confront their ignorance. This unit is designed to teach students to think like a scientist, to formulate actionable questions, collect, graph, and analyze data. I want to teach students to formulate questions to guide their research, thinking, and curiosity. Ideally, the skills taught in this unit will transfer and serve as a springboard for their future learning endeavors.

Rationale

Once I learned I was going to attend Paul Turner's Asking Questions in Biology Discovery versus Knowledge seminar, I began looking for resources and found Warren Berger's book titled The Book of Beautiful Questions. My mind was racing as I reflected on my practice and wanted to explore some of his suggestions for the classroom. Berger spoke about how students need to develop their own questions and how this practice will increase student engagement. My brain immediately went to a math unit I created for the Yale National Initiative in 2023 titled "A Framework for Problem Solving: Schema Development and Discourse," in which students had to create word problem questions when given a scenario, draw tape diagrams and solve their problems. They understood how to formulate multistep problems with different operations, which transferred to their own problem-solving ability. The discussion, engagement, and excitement for problem solving was the best I had seen in nearly thirty years as a teacher. I realized that I need to continue to teach the unit and share it as broadly as I can https://teachers.yale.edu/curriculum/units/2023/3/4. More importantly, I want to use student-formulated questions to drive learning throughout my teaching practice.

Background content

Skin

Skin is the largest organ in the human body. The three main layers are epidermis, dermis, and hypodermis (see Figure 1). The primary function of skin is protection from bacteria, germs, sun, rain, and other elements. The epidermis also makes new cells to replace ones that are shed and provides skin color. The dermis, the layer below the epidermis, has collagen and elastin which make it strong and flexible. The dermis contains, hair follicles, sweat and oil glands, nerves, and blood vessels. The hypodermis is the bottom layer. It is fatty, provides cushion, connects to muscles and bones, regulates body temperature, and contains larger blood vessels and nerves.[1]

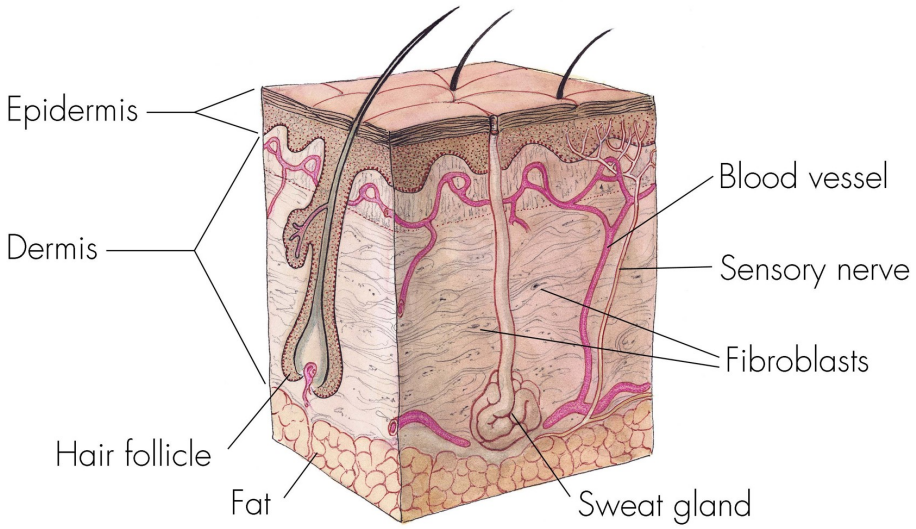


Figure 1: Skin cross-section; Courtesy of National Institute of General Medical Science (NIGMS)

The epidermis protects the dermis including the nerves, the sweat glands, and the ridge pattern. If the dermis is damaged, either through an injury or disease, a person could scar or permanently damage the ridge pattern.[2]

Have you ever stayed in the bathtub or a pool too long? What happens to your fingers and toes? They become wrinkly or prune. Do you know why? It is because the skin on our hands and feet absorb the moisture. The rest of your body does not. Do you know why? What might repel water? Oil. The skin on the rest of our body has sebaceous oil glands. Why would we not want our hands and feet to be oily? Would oily skin help with our grasp? Oil would hinder our grip because it is slippery and causes less friction.

Taxonomy

Taxonomy is the study and classification of living and extinct species. Carl Linnaeus was a Swedish naturalist, known as the Father of Taxonomy. He first described the binomial nomenclature system in his 1735 work *Systema Naturae* which classified plants and animals into kingdom, class, order, genus and species. Over time, the system expanded. Today it includes the categories: kingdom, phylum, class, order, family, genus, and species.[3] Figure 2 shows how humans, primates, and koalas are classified, which will be relevant in the fingerprint section below.

	Humans	**Primates**	**Koalas**
Kingdom	*Animalia*	*Animalia*	*Animalia*
Phylum	*Chordata*	*Chordata*	*Chordata*
sub Phylum	*Vertebrata*	*Vertebrata*	*Vertebrata*
Class	*Mammalia*	*Mammalia*	*Mammalia*
Subclass	***Placentalia***	***Placentalia***	***Marsupialia***
Order	*Primates*	*Primates*	*Diprotodontia*
Suborder	*Hominoidea*	*(varies)*	*Vombatiformes*
Family	*Hominidae*	*(varies)*	*Phascolarctidae*
Genus	*Homo*	*(varies)*	*Phascolarctos*
Species	*Sapiens*	*(varies)*	*Cinereus*

Figure 2: Taxonomic Classification Chart

Species with Fingerprints

The uniqueness of fingerprints was recognized for thousands of years, yet the discovery and understanding of fingerprints is the source of much debate. Why do humans have fingerprints? How do they form? Why do primates, humans, and koalas have fingerprints, whereas other animals do not? I believe my students will be interested in fingerprints and curious to learn more about them. Fingerprints are an evolutionary adaptation with which scientists are grappling to better understand. It is interesting that humans, primates, and koalas have fingerprints, but not other mammals that climb trees and have dexterity such as raccoons. Human fingerprints and an adult koala's fingerprints are so similar that an electron microscope cannot distinguish between the two.[4] However, koalas only have ridges on their fingertips and on parts of their palms, while humans have ridges on the entire palm and fingers. Some scientists may argue that the fingerprint

characteristic may have evolved before the mammalian split into placental and marsupial occurred. The mammalian split into placental and marsupial groups occurred early in the Cretaceous period about 130 million years ago.[5] In which case many more animals that climbed trees in the forest would have had fingerprints. Did the fingerprint trait disappear from many mammals and marsupials as did our tails? It seems unlikely. Why would the trait disappear if it helps arboreal mammals to survive? Another viewpoint is that koalas and humans both have fingerprints because of convergence, meaning that two lineages developed the traits independently through natural selection and not through a common ancestor.[6] Henneberg et al makes the claim that the adaptations evolved in arboreal environments to help grasp branches.[7] Fingerprints seem to be an adaptation for climbing as a result of environmental selection pressure.[8] Thus, fingerprints on humans and koalas would be an example of independent trait evolution.

Formation of Fingerprints

Special skin, or friction skin, forms on the hands and feet of primates. It is thicker than other skin and is adapted for climbing and grasping. It also contains many more sweat pores. Friction skin forms in the fourth week of pregnancy and generally does not change throughout a person's lifetime, unless there is injury or disease. There is not one commonly accepted way that fingerprints form. The authors Kücken and Newell have observed fingerprints to determine how they form. In their 2005 article, they describe how they have used computer modeling and the outcome supports their previously-made observations. The ridge patterns and volar pads are closely connected.[9] The primary ridges form around the thirteenth gestational week. Sweat glands form in week sixteen and primary ridge formation terminates by week seventeen. Then smaller secondary ridges form. Volar pads are present during weeks nine through fifteen of gestation. According to Kücken and Newell, the epidermis is layered on top of a more fibrous amorphous dermis. The epidermis meets the dermis at the basal layer, and here cells form columns with an axis that is perpendicular to the skin surface. The basal layer then forms waves or undulations and form folds. The folds become the primary ridges. The patterning waves determine the fingerprint pattern type. Glover et al, shows that the unique fingerprint patterns are produced by a Turing reaction that is named after Alan Turing who showed with mathematical models how high-level patterns such as zebra stripes and leopard spots emerge due to particle diffusion and chemical reactions.[10]

Hypotheses

Since scientists strive to understand dermatoglyphics, they ask questions and propose hypotheses to determine the best explanation with the facts that they have at the current time. Henneberg et al, proposes two hypotheses to explain the dermatoglyphic similarities across species. "(1) dermatoglyphic similarities, due to high heritability of dermatoglyphic patterns, are an expression of genetic similarities, (2) dermatoglyphic similarities due to dermatoglyphic pattern configuration being dependent on the morphology of underlying structures, are an expression of functional, biomechanical similarities."[11] Henneberg et al, then explains that the first hypothesis (1) can be proven false by showing that the similarities in fingerprint patterns are from distinctly separate taxa and the second hypothesis (2) can be corroborated by showing similar dermatoglyphic patterns in species that have diverse taxonomies.[12] This example demonstrates how scientists ask questions to work through the vast unknown, or area of ignorance, to explain the world around them.

There are various hypotheses to explain the purpose of fingerprints. Hoffman et al, makes the claim that enhanced sense of touch, known as the Fruit Texture hypothesis, suggests that fingerprints evolved to sense texture and determine the edibility of fruit.[13] When the ridges of a fingerprint rub over a surface, amplified

vibrations occur. Our skin contains mechanoreceptors for fine textures and coarse textures.[14] The ridges enhance tactile sensitivity which scientists theorize helps animals determine the ripeness of fruit. Knowledge of how vibrations aid tactile sensations has potential to help improve prosthetic hand development in the future. The second hypotheses proposes that fingerprints improve grip by creating friction. Recently, Yum et al, describes how the fingerprint ridges control moisture thus enhancing grip in wet and dry situations. When the hands are wet, the ridges move the water away as ridges in a landscape funnel the water to the valleys. When the hands are dry, the abundance of sweat glands produce sweat to create moisture. Sometimes when our hands are too dry to pick up a piece of paper, people lick their fingertips to add moisture and improve their grip. Interestingly, new world monkeys, which are those found in Mexico, Central and South America have “tailprints” on their prehensile tails, which are used to grip branches.[15] Tailprints seem to provide compelling evidence that fingerprints form to help with grip. The various hypotheses that scientists have developed to explain aspects of fingerprints provides a glimpse of how scientists ask questions to come to some understanding and cut through a vast area of ignorance.

Fingerprint Types

The three most common patterns of fingerprints are arches, whorls, and loops (See Figure 3).

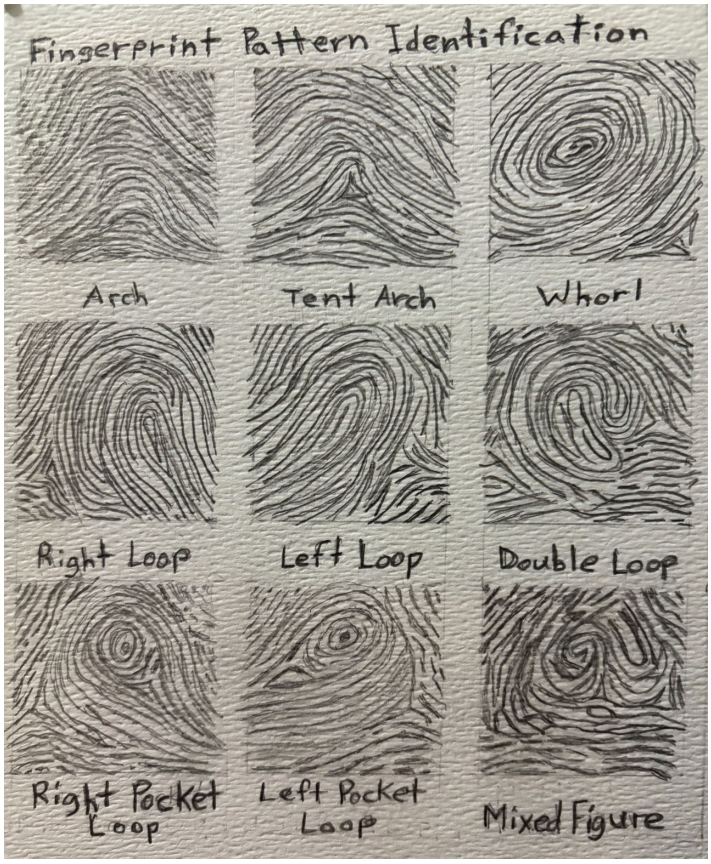


Figure 3: *Image hand drawn by Valerie Schwarz*

Arches are in the shape of arches similar to the image I conjure up in my head of an engineered structure such as a Roman aqueduct, a bridge, or a doorway. The tented arch comes to more of a point. Arches make up only 5% of the populations’s fingerprints. Loops go to one side of the digits. There are ulnar and radial loops. Ulnar loops are the most common and they curve toward the pinky or the side with the ulna bone. The

radial loops curve backwards toward the thumb and the radial bone. Loops are the most popular type and comprise of 60-65% of fingerprints. There are left and right loops which indicate the side the ridges enter and leave. Whorls have concentric pattern of ridges in the center and comprise 35% of fingerprints. Double loops are a type of whorl in which two separate loops intertwine forming an S or W pattern. Pocket loops make complete circles, and the left/right direction tell the direction the loops enter and exit. A mixed figure combines two or more of the fingerprint patterns forming a rare and complex pattern. Triradii form a Y-shaped pattern with ridges intersecting from three different angles.[16]

Fingerprints as Identification

Since fingerprints are unique, they are used for identification, which may be to solve a crime or to identify a body. The use of fingerprints as unique identifiers dates back to Babylon and ancient China. According to a timeline in The Forensic Laboratory Handbook, a novel from China in 1200 used fingerprints in a criminal investigation. Knowledge of the ridges, pattern class, and use in fraud prevention developed from the 1600-1800. In 1890, Argentina developed the first fingerprint identification system to aid police investigations and in 1892, Argentina solved its first criminal case with the use of fingerprints.[17] The Federal Bureau of Investigation (FBI) in Washington, D.C. established the FBI Identification Division in 1924 because the police throughout the nation saw a need for a central location of fingerprint cards and arrest records.[18] Today, every country in the world stores fingerprint records, and some fingerprints have been digitalized.

More recently fingerprints are used for cybersecurity. Fingerprints are used for account protection and fraud detection. An example of account protection is that Apple computers use Touch ID to protect your device and privacy. Once Touch ID is set up, a sensor can easily read a fingerprint and allow or deny access.

Collecting and Analyzing Fingerprints

Our fingers pick up oils and dirt when our hands touch our face, hair, or objects. Then when our fingers touch objects we leave fingerprints behind. Some fingerprints are visible such as ones left on a computer screen, a mirror, or a cell phone. Others are hidden, or latent. Police and detectives look for prints visible and latent as a tool to solve crimes. Fingerprints from a crime scene must be handled carefully by an examiner. An important step in crime scene investigation is to gather the prints of all persons who regularly enter the space where the latent fingerprint was discovered. Detectives will gather inked prints from the people called elimination prints. Sometimes only fragments of the print exist, which makes analysis more difficult.

A variety of powders and chemicals are used to “develop” latent prints. Visible prints should be photographed. Prints that are found in dust or are greasy or bloody should not be brushed with powder as this will destroy them. Fingerprints that are wet must first be dried. Forensic scientists lightly brush powder over a “latent-bearing surface” and the powder sticks to the grease or moisture in the ridges, making the print visible. The color of the powder should contrast the color of the surface to make the fingerprints more prominent. Gray or black powder are preferred. Gray works well on mirrors and polished metal surfaces, while black works well on light -colored surfaces. Once the prints appear, the brush strokes should follow the direction of the ridges. Beginners tend to use too much or too little powder. Once the prints are dusted, they should be photographed before they are lifted using rubber and transparent tape. Black powder should be lifted on white tape and gray powder on black tape to enhance the contrast. The tape has a film over it that is removed before taking the print, and the print collector must be careful to avoid getting their own fingerprints on the tape. The print is then labeled including the operator (collector), date, and object from which it was collected.[19]

As a part of this curriculum unit, students will not only learn how to ink their own fingerprints, but also how to

find and lift fingerprints around the classroom. The students will explore how their fingerprints are visible on Scotch™ tape and on computer and cell phone screens. They will also explore how to use powders, brushes, and tape to lift fingerprints. As a part of learning to think like a scientist, the students will collect and analyze data some of which will include fingerprints.

Data Cycle

According to Boston University, "Data science is emerging as one of the most sought-after career paths of the 21st century."[20] So it is no surprise that in 2025, there was a big push in Virginia to include the Data Cycle into lessons across all content areas. The Data Cycle as described by the Virginia Department of Education (VDOE) has four steps. They are: 1) formulate questions 2) collect or acquire data 3) organize and represent data and 4) analyze data and communicate results. In fourth grade, we review bar graphs from third grade, but the focus is line graphs. Students use the data cycle and create line graphs. An important understanding is that line graphs represent data over time. The data cycle is an important component of what scientists do as they work from discovery to knowledge.

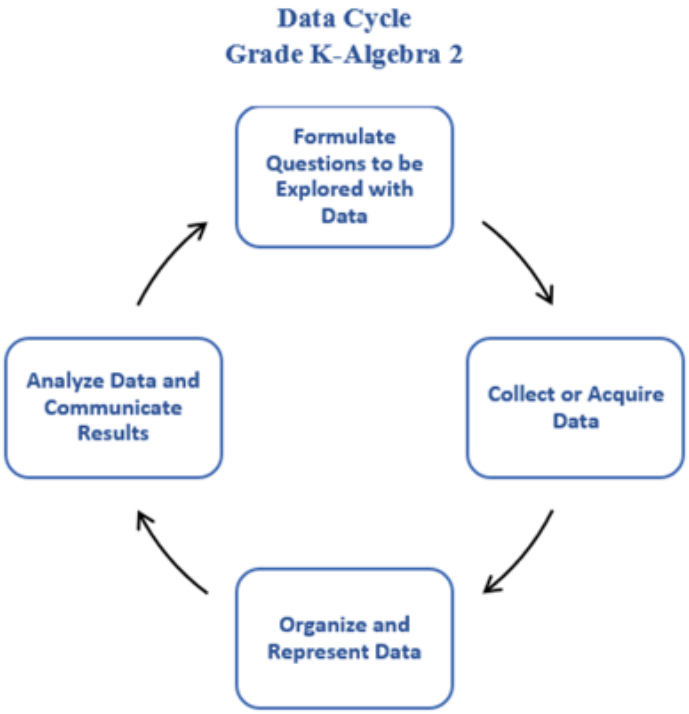


Figure 4: The Data Cycle - Courtesy of: *Focus on Mathematics Implementing the Data Cycle* © 2025 by the Commonwealth of Virginia, Virginia Department of Education. All rights reserved. Reproduced by permission.

Questioning

In addition to scientists and inventors, venture capitalists ask questions that often lead to innovation. Netflix is a company that came to fruition because of a question. Warren Berger, author of *Beautiful Questions in the Classroom,* explains how Netflix was created when the founder asked why he should have to pay the late fees

at Blockbuster? He wondered why no one had come up with a better way. More questions flooded his mind. What if the video rental business was more like a health club? Just like that, Netflix was born! The business continued to evolve in response to more questions. Why are we only renting films and shows? What if we made them too?[21] I want my students to learn how to formulate their own questions and use them for a purpose. Questioning will allow students to explore science, history, math, or any subject matter. It will teach them to be creative and innovative. I want to spark curiosity, engagement, and passion within my students and show them that asking questions is beneficial and not something to fear!

Questioning is a skill that separates humans from other primates. From an early age young children ask questions to gain new information and make sense of the world around them. When children learn to talk, they ask questions to learn the names or labels for objects. Paul Harris, a child psychologist from Harvard, reports that a child could ask about 40,000 questions between ages 2-5.[22] As young children's vocabulary develops between ages 2-5, the types of questions they ask also shifts from "Who?" "What?" then adding in "Where?" and "How?" and "Why?" as they try to understand how things work. As children ask questions their brains are making connections – about a quadrillion!! Research has shown that asking questions triggers reward processing, so it feels good and creates joy.

Studies show that as children enter preschool the number of questions they ask declines. This has been shown in various cultures throughout the world. Through research, a British psychologist, Susan Engel, found that children asked up to 26 questions per hour at home however, the number of questions asked for the same children dropped to two per hour at school.[23] Berger emphasizes that questioning stops in school. The article "The Creativity Crisis" published in *Newsweek* reports that, "Preschool children, on average, ask their parents about 100 questions a day. By middle school, they've pretty much stopped asking." Figure 5 shows the decline in questioning that occurs with children.

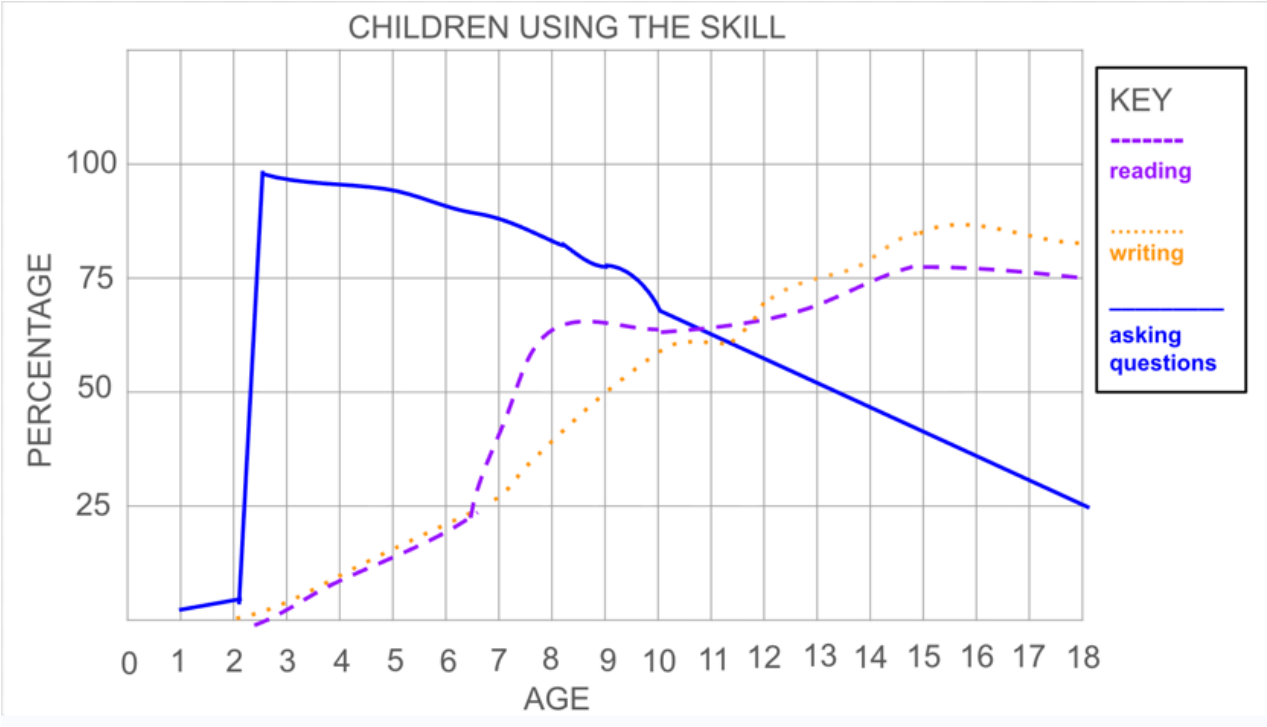


Figure 5: The decline in questioning with age based on data from The Right Question Institute

There are several scientific reasons to support the decline in questioning. In young children the brain is rapidly forming synapses and connections, but around age five, “synaptic pruning” curtails the amount of questioning. Synaptic pruning is a natural process where our experiences strengthen the most relevant circuits and the weakest circuits fade.[24] As young children develop mental models and categories to understand the world, they do not ask to identify as many things around them. However, these neural changes alone do not fully explain the sharp decline in questioning, particularly in schools.

Berger lays out five enemies of classroom questioning: fear, apathy, ignorance, time, and culture. As a classroom teacher with almost 30 years of experience, I have seen all these questioning enemies play out in the classroom. Students are fearful of being wrong, fearful of showing their vulnerability that they do not understand a topic, and fearful of the perception of their peers. They may be afraid to look “nerdy” or show that they care about learning. They may be fearful that their question will be perceived as “wrong.” I have seen apathy play out when a student acts as if they do not care about learning because the reality is they struggle in their learning journey. It is easier to not care than to show one’s vulnerability. Some students do not care about learning, and some students bring trauma and other circumstances beyond their control, perhaps hunger or home situations that preoccupy their mind that limit the bandwidth for learning. Conformity and compliance are often required of students which can result in an unintended consequence of apathy. I have seen ignorance when a student may not have background knowledge, or may not understand the lesson, and they do not know what to ask. There often is a fear of looking ignorant. Berger states that while some questioning may be an innate skill, other questioning must be learned and practiced. If the innate questioning is not used for many years, “the question-asking muscle” (as Rothstein calls it) atrophies it must be strengthened.[25] The first three enemies to questioning, fear, apathy, and ignorance, seem to relate more to the students and the way they feel. The next two, time and culture, seem to relate to the teacher. Time is scarce with the vast number of standards that must be covered, and high-stakes testing has increased the pressure on students and teachers. In my quest to get through the required material, I often find myself limiting the number of questions I have the capacity to answer. Sarah Westbrook from the Right Question Institute (RQI) says, “We try to show that questioning can be a shortcut to deeper learning, rather than a detour.” She also explains that students’ questions reveal gaps in student understanding and thus enabling the teacher to fill in the gaps.[26] Berger considers the culture of the classroom as an enemy. The culture of a room where students are afraid to ask questions and afraid to be wrong certainly would be inimical. Berger makes the case that schools were designed during the Industrial Age and focused on compliance and memorization. While these skills may have been desirable during the Industrial Age, the 21st -century is more suited for innovation and independence.[27] Knowing the enemies of questioning is vital as I design a curriculum unit to promote an environment where students will ask questions and formulate their own questions to drive their learning.

Create a Questioning Culture

According to Warren Berger, “Questioning is one of the most important and underrated skills a person can possess. It enables us to learn, understand, explore, adapt, and communicate.”[28] As the teacher, it is up to me to foster a culture where students are encouraged and taught to formulate their own questions. The students must first feel comfortable, valued, and willing to take risks.

This is clearly to the detriment of the students. After reading many books about questioning and the importance of having students formulate their own questions, I am going to figure out how to change my current practice, so that students are driving the questions. I want to become proficient with the questioning strategies and consummate at directing the focus through questioning techniques.

The Right Question Institute developed the Question Formulation Technique (QFT), which is described in more detail in the book, *Make Just One Change Teach Students to Ask Their Own Questions*. The authors of the book are also the founders of The Right Question Institute. The six core components of the QFT are:

- A *Question Focus* is typically created by the teacher, as I did with oceans (see below)
- Students *produce questions*
- Students work to identify and manipulate *closed- and open-ended questions*
- Students select *priority questions*
- A teacher and students determine *next steps*– what they will do with the priority questions
- Students will complete a *reflection* activity[29]

This past spring, I tested out a strategy that Berger suggested in preparation for the development of this unit. I had my students write as many questions as they could in a short period of time about a topic. Our topic was oceans, and the students were so engaged. After the students wrote their questions I took them and developed a short slide presentation based on them. One student, who loves bunnies, asked, "Why aren't there bunnies in the ocean?" For fun I looked it up, and discovered that there are rabbit fish, whose mouths resemble a rabbit's mouth and sea bunnies, which are mollusks without shells that live near Japan. I shared my discoveries with the class and showed them how questioning is a great way to learn more about topics about which they are passionate.

As I use the QFT protocol with this unit, I will teach the students to categorize questions as open and closed. Warren Berger describes questions as closed and open. Closed questions are questions that have a definitive answer. They may be "yes" or "no" questions or factual questions such as "How many ounces in one pound?" Open questions do not have a definitive answer. They tend to start with how, why, or what if. The next step is for the students to prioritize the questions, then we will decide the culminating project together. I will include a suggestion in the activities section.

Teaching Strategies

Question Formulation Technique (QFT)

The QFT strategy is designed to teach students to formulate their own questions and drive their own learning. The use of the strategy should increase student engagement and promote deeper learning. This strategy will be used throughout the unit.

Notice and Wonder

The *Notice and Wonder* strategy engages students in mathematical or other discourse. Students look at a graph, image, or other learning material and share what they notice and what they wonder. The strategy has multiple entry points and is low risk, which fosters participation and confidence. The teacher can facilitate the conversation to build on what the students share.

Slow-Reveal Graphs

A *Slow-Reveal Graph* is an instructional routine that gradually reveals parts of a graph to increase

engagement. The graph uses slides with animation to bring in a new feature with each slide. Students analyze, interpret, and make predictions about the graph.

Experiential Learning

The students will engage in hands-on, experiential learning throughout the unit. This strategy is beneficial for students to learn through kinesthetic methods such as making fingerprint art with ink pads, creating graphs with authentic data collection and the use of rulers. Students will explore scientific concepts such as friction and vibration though hands-on activities.

Collaborative Data Collection

The class will work to collect fingerprints from the entire class. They also will collect fingerprints from students or adults in the building to increase the sample size. The class will also make graphs about the amount of questioning and friction which includes collaborative data collection.

Activities

The unit will begin the first day of school with a get-to-know-you activity. The unit's activities will intertwine teaching and learning about fingerprints, data cycle and graphing, and questioning strategies. The activities for days 6-16 use the Question Formulating Technique (QFT) culminating with a research project including a graphing component. The class will determine the final project. These activities are designed to introduce students to questioning. Since it is the beginning of the year, my goal is to use these activities as a framework throughout the year. I expect the students' level of questioning and ability to formulate questions, use the data cycle, and complete projects driven by their questions will increase throughout the year.

Day 1: The students will make fingerprint art to celebrate their uniqueness and introduce themselves to the class.

Day 2: The teacher will introduce the Notice and Wonder strategy as the class looks at different fingerprints to discover loops, whorls, and arches. Then they will collect and graph their fingerprint types. Science World in California has a nice identification card on its website.
https://www.scienceworld.ca/wp-content/uploads/attachments/resources/FingerprintPatterns.pdf

Day 3 and Day 4: The class will expand the sample size. They will collect 100 fingerprints and see if the data gets closer to the percent of the population with each type of fingerprint.

Day 5: The students will experience a Slow Reveal Graph using the line graph (Figure 5) that shows the decline in student questioning.

Day 6-16: The teacher will collect data about the number of questions the class asks without letting them know.

Day 6: The students will conduct an experiment to see how many pencils they can pick up using food service gloves given different conditions.

Day 7: Students will have 15 minutes to work in collaborative groups to write as many questions as they can think of about fingerprints. The students will classify their questions as open or closed.

Day 8: Then the students will practice turning open questions into closed questions and closed questions into open questions. Each group will prioritize their top two questions and determine their project.

Day 9 & Day 10: Students will conduct research.

Day 11-16: Students will write and work on their project.

Day 17: Students will make a line graph with their questioning data and analyze the data by answering questions about the graph.

Day 18: Students will reflect on what they learned about questioning.

Activity 1: The first day of school (Day 1) will begin with the students making an art project to introduce themselves to the class. The students will make fingerprint and thumbprint drawings based on *Ed Emberley's Complete Funprint Drawing Book*. The class will learn their classmates' favorite subjects, sports, animals, friends, celebrities, and places to visit. The class will see that their classmates are as unique as their fingerprints.

Activity 2: The second activity is from Day 2. The students will analyze the patterns of fingerprints as they discover loops, arches, and whorls with teacher guidance and support. Then the students will use ink pads to collect their fingerprints, so that they can classify them as loops, whorls and arches. Then the class will make a bar graph to represent the data. The students will expand the data sample of fingerprints from about 20 to 100 over Days 3 & 4. The class will collect fingerprints from other students and adults in the school. They will classify them and make a second bar graph. They will have to see if the sample of 100 fingerprints from the school population yields data closer to the actual percentages found in the world's population.

Activity 3: On Day 6, the students will conduct an experiment, collect data, and make a line graph. The students will work in collaborative groups. They will wear food-service gloves and pick up as many pencils as they can in 30 seconds. The pencils must be picked up one at a time. Some pencils will be in cooking oil, some will be in water, and some will be dry. The number of pencils will be recorded after 10 seconds, 20 seconds, and 30 seconds. Each student will then plot their own data into a line graph.

Activity 4: The students will work through the QFT during Days 7-16. This will be the first time the students will go through this process. The questions that they formulate will drive their final project. The students will use this process throughout the school year with other topics.

Activity 5: Some ideas for the final project include making a book, multimedia project, or a mystery about the unit. The students may have other ideas, but the project will have to incorporate all three components. It will require questions to guide the research, data collection, information about fingerprints, and a final product.

https://www.academia.edu/27860920/Fingerprinting_a_chimpanzee_and_a_koala_Animal_dermatoglyphics can resemble human ones. This article was helpful to explain the different hypotheses.

About Touch ID Advanced Security Technology - Apple Support. Accessed July 14, 2026. https://support.apple.com/en-us/105095. This website was useful to explain how fingerprints are used for cybersecurity.

Berger, Warren, Elise Foster, Dan Rothstein, and Luz Santana. *Beautiful questions in the classroom: Transforming classrooms into cultures of curiosity and inquiry*. Thousand Oaks, CA: Corwin, 2020. This book provided the majority of the background information about questioning and the QFT.

Berger, Warren. *The book of beautiful questions: The powerful questions that will help you decide, create, connect, and lead*. New York: Bloomsbury Publishing, 2019. There was a lot of overlap with Warren Berger's Beautiful Questions in the Classroom book.

Controlled hydration in epidermal ridges probed by thz time-domain spectroscopy | IEEE conference publication | IEEE xplore. Accessed June 22, 2026. https://ieeexplore.ieee.org/document/8873980/. This article provided information about how the ridges of fingerprints help regulate moisture.

Convergence as evidence. Accessed June 22, 2026. https://www.researchgate.net/publication/275159164_Convergence_as_Evidence. This article provided information about convergence, or the explanation that fingerprints are an adaptation that developed independently in humans, primates, and koalas.

Core concept: How synaptic pruning shapes neural wiring ... Accessed July 14, 2026. https://pmc.ncbi.nlm.nih.gov/articles/PMC7368197/. This website provided information about synaptic pruning.

Cummins, Harold. "The Topographic History of the Volar Pads (Walking pada; Tastballen) in the Human Embryo." *Contrib Embryol* 20 (1929): 103-126. I used one fact from this author that was cited in the Kücken and Newell Fingerprint Formation article page 72.

The Forensic Laboratory Handbook: Procedures and practice by Ashraf Mozayani; Ashraf Mozayani (editor); Carla Noziglia (editor) | hardback | December 1, 2005 | Humana Press 1st edition | 9781588294647 - biblio NZ. Accessed June 22, 2026. https://biblio.co.nz/book/forensic-laboratory-handbook-procedures-practice-forensic/d/1734882726. I used chapter 6 from this resource. It was easy to understand and provided important background content about fingerprints.

Glover, James D., Zoe R. Sudderick, Barbara Bo-Ju Shih, Cameron Batho-Samblas, Laura Charlton, Andrew L. Krause, Calum Anderson, et al. “The Developmental Basis of Fingerprint Pattern Formation and Variation.” *Cell* 186, no. 5 (March 2023). https://doi.org/10.1016/j.cell.2023.01.015. I used this article to better understand fingerprint formation during pregnancy.

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Zealand International Symposium on the Forensic Sciences (1996. 1998).

The importance of touch and friction to the evolution of fingerprints in primates. | young anthropology. Accessed June 22, 2026. https://jps.library.utoronto.ca/index.php/ya/article/view/37816. This article explained how fingerprint ridges enhance touch to determine fruit ripeness.

Janke, A, G Feldmaier-Fuchs, W K Thomas, A von Haeseler, and S Pääbo. "The Marsupial Mitochondrial Genome and the Evolution of Placental Mammals." *Genetics* 137, no. 1 (May 1, 1994): 243–56. https://doi.org/10.1093/genetics/137.1.243. This article was useful for exploring the placental and marsupial evolutionary split.

Kücken, Michael. "Models for Fingerprint Pattern Formation." *Forensic Science International* 171, no. 2–3 (September 2007): 85–96. https://doi.org/10.1016/j.forsciint.2007.02.025. This article was useful to understand fingerprint formation and scientific modeling. The mathematical equations were complex and not useful for my purposes.

Prevost, Alexis, Julien Scheibert, and Georges Debrégeas. "Effect of Fingerprints Orientation on Skin Vibrations during Tactile Exploration of Textured Surfaces." *Communicative & Integrative Biology* 2, no. 5 (September 2009): 422–24. https://doi.org/10.4161/cib.2.5.9052. This article explained how fingerprint ridges cause vibrations which help identify smooth and rough textures.

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The science of fingerprints: Classification and uses. U.S.: Empire Books, 2011. This book was complicated, but I was able to use information about how fingerprints are lifted.

Trusting what you're told — Harvard University Press. Accessed July 20, 2026. https://www.hup.harvard.edu/books/9780674503830. This book was the original source for the statistic about the number of questions children ask between ages 2-5 referenced in Berger's Beautiful Questions in the Classroom book.

Warman, Peter H., and A. Roland Ennos. "Fingerprints Are Unlikely to Increase the Friction of Primate Fingerpads." *Journal of Experimental Biology* 212, no. 13 (July 1, 2009): 2016–22. https://doi.org/10.1242/jeb.028977. This article explained how new world monkeys have tailprints. It also discussed several hypotheses for fingerprint adaptation.

Yum, Seoung-Mok, In-Keun Baek, Dongpyo Hong, Juhan Kim, Kyunghoon Jung, Seontae Kim, Kihoon Eom, et al. "Fingerprint Ridges Allow Primates to Regulate Grip." *Proceedings of the National Academy of Sciences* 117, no. 50 (November 30, 2020): 31665–73. https://doi.org/10.1073/pnas.2001055117. The first few pages of this article explained how fingerprints can help regulate moisture and possibly improve prosthetics.

Appendix on Implementing District Standards

The standards listed below are Virginia Standards of Learning. This unit is cross curricular, but the primary focuses are science and mathematics. The science standards are 4.1 and 4.2.

Science standard 4.1 states: The student will demonstrate an understanding of scientific and engineering practices, then it lists points a-f. The points that best fit this curriculum unit are a) asking questions and defining problems, c) interpreting, analyzing, and evaluating data and f) obtaining, evaluating, and communicating information. This curriculum unit addresses this standard through activities that relate to asking questions, the data cycle, and the final project.

Science standard 4.2 says: The student will investigate and understand that plants and animals have structures that distinguish them from one another and play vital roles in their ability to survive. Key ideas include b) plants and animals have different structures and processes for obtaining energy. The fingerprint portion of this curriculum unit aligns with this standard since humans, primates, and koalas have fingerprints. Though there is still much debate, fingerprints are a structural adaptation most likely used for grip and for sensing the texture of food which enable humans, primates, and koalas to obtain food and obtain energy.

Mathematics standard 4.PS.1 describes: The student will apply the data cycle (formulate questions; collect or acquire data; organize and represent data; and analyze data and communicate results) with a focus on line graphs. This standard is addressed with the fingerprint bar graph, the slow reveal graph, the friction/pencil graph, the class questioning data graph, and through the graphing in the final project.

Mathematic standard 4.PS.2 states: The student will model and determine the probability of an outcome of a simple event. This standard is addressed when the students increase the fingerprint sample size to 100 and compare their data to the percent of the population with each type of fingerprints.

Notes

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