



Heart Rate Detectives: Exploring Human Biology Through Data and Inquiry

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At the Heart of the Matter

The heart is an essential part of our lives. Some would say that it guides our actions in romantic relationships, helps us care for loved ones, and even gives us courage when we face tough situations. In stories and films, we fall in and out of love, guided by our hearts. Men wage war because of heartfelt sentiments of honor and pride. Parents and caregivers sacrifice everything because our hearts implore us to provide the best for our children and loved ones. In many ways, the heart has taken on a mythical, larger-than-life role in major events in our lives because it guides how we navigate interactions at milestones and in relationships. However, what most people fail to explore until much later in life is the heart's function and health. What would happen if we focused more on the science of how our hearts work?

The curriculum unit, Heart Rate Detectives, is designed to engage 5th-grade students in learning concepts about human biology, math, and scientific study. This unit will allow students to explore how their heart responds to physical activity. As part of this investigation, students will use data analysis skills, including data collection, computation, and graphing; critical thinking; questioning; and scientific study.

During this ten-day unit, students will have the opportunity to become scientists and mathematicians. Students will investigate and gather authentic data about their physiology. The trends that they observe and their findings will then be communicated to their classmates, other students, and community members through presentations and reports. This experience will provide students with a meaningful way to learn and practice math and science concepts.

School Profile

I currently work in a small school in a mid-sized school district in Richmond, Virginia. Bellevue Elementary School has 200 students, and we are categorized as a Title I school. I serve as a math Interventionist in my current school. Our school focuses on providing instruction in reading, math, science, and social studies. Our

population includes 70% of students who identify as African American, 10% who identify as White, 6.3% who identify as biracial, and 1.9% who identify as Latino. We have students with Individualized Education Plans and Multilingual learners included in our population. Currently, our science and math data indicate many opportunities for improvement. Specifically, our students have had major gaps in measurement, computation, problem-solving, data analysis, and experimental design. As an Interventionist, it is my job to identify students who are performing 2 or more grade levels below their current grade level in mathematics using relevant data such as state assessment scores, classroom assessments, and a universal math screener. I am often tasked with helping students improve their math skills in the identified areas of weakness.

The Heart Behind the Lesson

I selected this topic because it directly connects to the areas of improvement identified in our state testing data. This unit also connects to students' lives by helping them link physical activity to their overall health. Many elementary students are aware that exercise is important, but they usually lack opportunities to investigate the science behind how their bodies function.

Heart rate is an ideal topic because it allows students to see changes in their own bodies. Students can see firsthand how activity level affects overall heart function and connect this data to research. Additionally, the topic is a great way to utilize a cross-curricular approach that meets our instructional needs identified through data disaggregation. Math and science are often taught in isolation. Still, this approach gives students a cross-curricular opportunity to practice skills in each subject while helping them make connections to the real world.

The unit also highlights one of our core approaches as a STEM school: inquiry-based learning. When students have the opportunity to identify problems, ask questions, and explore answers or solutions, they often learn more about the topic. Allowing my students to be meaningfully engaged in learning about the cardiovascular system will transform their understanding of science and math in a way that completing a worksheet will not.

This curriculum unit will consist of a sequence of lessons that guide students through a ten-day investigation of heart rate and physical activity. Students will commence by examining how the body responds to different levels of activity and develop questions about factors that influence heart rate. They will explore basic concepts of the cardiovascular system, including the functions of the heart and blood vessels, as well as the circulatory system. Students will collect heart rate data at rest and after various forms of exercise, conduct repeated trials, work cooperatively with their peers, record observations, organize information in data tables, and use mathematical procedures to analyze their findings. By engaging in authentic investigations, students will improve critical thinking skills, strengthen data literacy, and improve their ability to solve complex problems.

Content Objectives

My unit will focus on analyzing data in both math and science. The math portion of the unit will focus on solving complex single- and multi-step problems. Students will also use mathematics to collect data and interpret it using stem-and-leaf plots, line plots, and measures of central tendency (mean, median, mode) and range. The science objectives are aligned with the math objectives because they focus on conducting investigations, interpreting data, and drawing conclusions based on the data. This unit is a great opportunity to provide a cross-curricular approach that helps students apply what they learn about the body's biological processes and make meaning of the data they collect.

The History of Heart Research

For about 500 years leading up to the early 1900s, individuals in the scientific and medical fields conducted numerous heart dissections; however, the findings on the inner workings and factors that contributed to heart health were inconclusive. A true understanding of its function and anatomy was still being explored.

The earliest knowledge of the cardiovascular system dates back to ancient Egypt. Egyptians were the first known civilization to embalm their dead. During this process, they cultivated an understanding of the heart's structure and were the first to attribute our emotions as one of the heart's primary functions. However, the Egyptians knew early on that the heart was an integral part of life. Diagrams of the heart from ancient papyrus have been discovered, and these renderings are similar to what we know about the heart's anatomy today[1].

Galen would later become an authority in medicine, and much of his work served as the basis of medical practice for many years. A student of Egyptian and Greek medicine, Galen became committed to disseminating medical knowledge and became a physician to an emperor. He conducted many dissections that became the basis of his knowledge. Galen expanded the body of knowledge about the heart by revealing that the arteries and vessels connected to the heart were filled with blood. This served as a conduit for blood to flow throughout the body[2].

William Harvey expanded on this work in the 1700s, explaining that the heart was responsible for pumping blood throughout the body. During the 1800s, René Théophile Hyacinthe Laennec created a wooden apparatus to listen to the heart[3]. This device would serve as a precursor to the modern stethoscope. By the mid-1900s, models of the muscular structure were being fleshed out by Francisco Torrent-Guasp, whose dissection showed muscular structure, looping arteries, and left and right chambers[4].

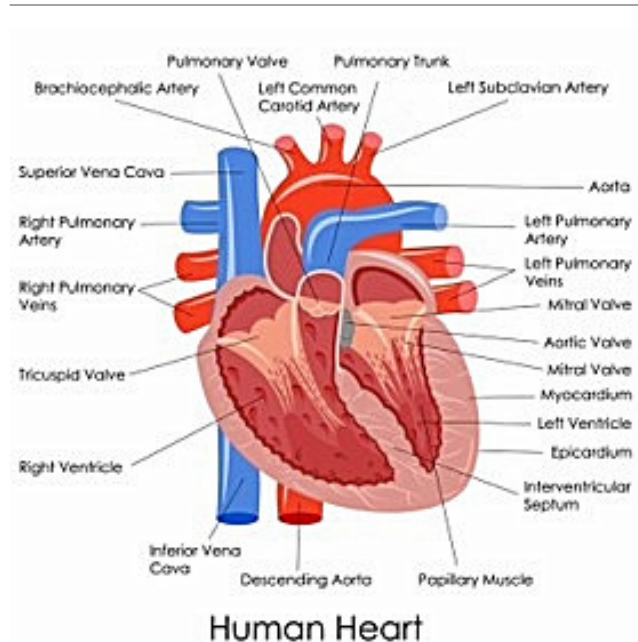
Much of our current knowledge about other health factors that contribute to our heart health or lack thereof is a byproduct of the Framingham Heart Study. The researchers posit that high blood pressure, diabetes, smoking, and obesity are the leading factors that contribute to heart disease[5]. This study was initiated in light of President Franklin D. Roosevelt's death[6]. During his presidency, President Roosevelt experienced elevated cholesterol levels that his physicians dismissed as trivial and of little consequence[7]. However, as time went on and the president's health declined, the medical community realized that a misdiagnosis had been made. More research was needed to better understand the comorbidities that led to the decline in heart

health[8]. At the time, heart disease represented the cause of death of 50% of Americans. Thus, the Framingham Heart Study was born[9].

This heart study represents the most exhaustive body of longitudinal research focused on heart health and the many factors that contribute to its health or decline. This longitudinal study began in 1948, in Framingham, Massachusetts. The study was a byproduct of the National Heart Act, spearheaded by President Harry Truman in 1948. Congress provided \$500,000 towards this research project[10].

One major limitation of this study is its focus on Caucasian participants in the Northeast. Therefore, the data gathered may not apply to populations of color or other socioeconomic groups. In addition, the data do not account for lifestyle differences across regions or for the dietary differences or lack of access to healthy food that different populations experience.

The Science of the Heart



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Pixers, *Vector Illustration of Diagram of the Human Heart Anatomy*

The heart is a complex organ that we have learned more about over time through extensive research and examination. This organ is the key to sustained life because, without medical engineering, life cannot be sustained if the heart is not functioning.

The Anatomy of the Heart

What we know shows that the heart sits in the middle of the chest and beats approximately 100,000 times per day[12]. It is roughly the size of a fist and pumps all the blood in your body through it, oxygenating it before it is transported to the other organs. In terms of structure, the heart is made of a unique type of muscle that isn't found anywhere else in your body. The four chambers of the heart perform different jobs essential to heart health. The right and left atrium are located at the top of the heart, and these two chambers are

primarily responsible for receiving blood from your lungs and other tissues and organs throughout your body. This blood is then transported to the bottom two chambers of your heart, the right and left ventricles. The right ventricle transports deoxygenated blood to the lungs, and the left ventricle transports oxygenated blood to the rest of the body[13].

The flow of blood from our heart moves in what many scientists describe as a circuit. One circuit, the pulmonary circuit, moves the blood from the heart to the lungs, and the systemic circuit moves the blood to all other parts of the body[14]. It's important to note that scientists describe the heart's functions as a circuit because of the way it moves, and this also relates to the electrical system within our heart's mechanisms.

The Heart's Electrical System

The sinoatrial node, often referred to as the SA Node, serves as the heart's pacemaker[15]. The SA Node is made up of distinct cells that create an electrical charge that keeps the heart beating. The beating is automatic and unaffected by the brain or any other organ when the heart is given oxygen and the necessary nutrients. Two branches of the autonomic nervous system affect the SA Node's function: the parasympathetic and sympathetic branches. These two branches work to either accelerate or slow the heart's beating[16].

The atrioventricular node, or AV Node, is another important part of the heart's electrical system. This part of the electrical system functions much like the SA Node, but is often slower. It helps slow your heart rate as your blood fills the atria. These electrical impulses are the automatic electrical signals that keep the heart beating[17].

Heart and Health

The gold standard for determining physical fitness is VO2 max. VO2 max measures the maximum amount of oxygen consumption. This measurement determines cardiovascular health and aerobic fitness[18]. As we age, our VO2 max decreases. This measurement is often used to determine if a person is experiencing heart failure[19]. Heart health can also be measured by other factors, including resting heart rate, heart rate recovery, physical activity, EKG results, and diet. In addition to the previously mentioned attributes, doctors often examine other health markers that can predict future heart health. Some of these health markers include hypertension, cholesterol, obesity, diabetes, smoking, exercise or inactivity, sleep, nutrition, and stress. Each of these factors can predict how your heart will perform in later years of life[20].

Blood pressure is another important predictor of heart health. A healthy blood pressure reading can be a predictor of healthy brain activity and heart health. Blood pressure is determined by measuring systolic and diastolic pressure. Each reading determines a different part of heart health. Systolic pressure measures the peak of pressure when blood flows through your veins; diastolic pressure measures the lowest point before the next heartbeat. It is often described as residual pressure[21]. Hypertension occurs when blood pressure remains consistently high over time. High blood pressure can damage the walls of the arteries. Hypertension is usually classified into stages 1 and 2. High blood pressure is often described as a silent killer because there are usually no signs of sickness until it is too late[22].

Lifestyle factors that affect heart health include stress, inactivity, salt intake, smoking, and alcohol consumption. Eating too much salt causes the body to retain too much water. This accumulation increases blood pressure because there is more water in the blood. Chronic stress has been shown to activate the sympathetic nervous system, and this trigger can impact the heart rate and blood pressure. As we will discuss in the section on the heart in motion, exercise can be one of the best ways to improve blood pressure and

heart health. It can impact resting heart rate and lower blood pressure[23]. Smoking tobacco regularly has been shown to damage your blood vessels. This factor can impact all of the organs in your body. Long-term cigarette smoke contains many chemicals that impact the makeup. Cholesterol is a natural substance produced by the body that aids in cell structure. However, if cholesterol levels are too high or too low, this can have a profound impact on how organs like the heart function.

The Heart of Culture

Research on the treatment and understanding of factors that contribute to heart health among minorities is a body of work that took many years to develop. For decades, the focus of heart research in America has been on White Americans. In recent years, research has shown that many different factors impact minorities, and African Americans, Hispanics, and Asians have higher incidences of heart disease and higher instances of morbidity.

The Equity of Heart Health

Disparities in medical research are not the only factors that impact minority groups. Access to insurance and medical care, as well as geography and socioeconomic factors, continue to exacerbate the problem[24]. Biases in health care and amongst practitioners have also greatly impacted access to quality medical treatment and prevention[25].

Amongst African Americans, heart disease remains the leading cause of death. African Americans have the highest rate of death due to heart disease amongst all other races and ethnic groups. Specifically, black men have the highest rates behind black women. African Americans also have higher rates of stroke and heart failure. Hispanics overall have lower levels of cardiovascular disease, but these rates are higher than those of White Americans. Puerto Ricans specifically have higher rates of heart-related deaths than any other Latino group. Asian Americans experience higher rates of coronary artery disease earlier in life than other racial or ethnic minorities[26]. The researchers argue that both treatment and education should vary amongst groups. disease is the leading cause of death.

Differentiated treatment is needed since each race or ethnic group deals with different predispositions and comorbidities. For example, African Americans would benefit from more education and prevention of hypertension and strokes as precursors to heart disease. Asian Americans would be best served by early screening for heart disease and screening for the genetic presence of certain proteins that predispose this population. Hispanics would benefit from education about risk factors and an understanding of diabetes as a precursor of heart disease[27].

The Heart in Motion

The heart is an organ directly affected by physical activity[28]. Studies show a direct correlation between energy expenditure and heart health. Studies have also shown that energy expenditure has decreased overall in larger countries such as the United States of America and the United Kingdom. This has led to higher levels of obesity in population samples. Heart health and efficiency have been proven to improve with increased amounts of high-intensity exercise coupled with low-intensity exercise. Heart rate recovery is also associated with heart health and reduced mortality. For these reasons, exercise remains one of the most important

factors in maintaining or improving heart health. Understanding how different types of physical activity affect heart health is important for sustaining overall fitness throughout life.

Other studies have linked exercise to overall endurance and other health markers. Long-term endurance exercise has been linked to improved digestion, increased heart rate variability, and a reduction in the overall age-related decline many people experience[29].

A healthy heart has a resting rate anywhere between 60 and 100 beats per minute. Athletes may have a resting heart rate as low as 40-50 beats per minute. Keeping the heart healthy depends largely on how often and how hard we push it beyond its resting rate. Stroke volume is the amount of blood that your heart ejects with each beat. Higher stroke volume is associated with better heart health, while lower stroke volume indicates the heart is not performing as efficiently. Cardiac output is the amount of blood your heart pumps out of its chambers in one minute. Stroke volume is one of the major factors that impact cardiac output.

Two types of exercise affect heart health: aerobic and anaerobic. Aerobic exercise is one of the best ways to improve Stroke Volume and Cardiac output. When we exercise, we ask our hearts to work harder, increasing blood flow throughout our bodies. Research shows that our arteries improve with regular aerobic exercise because stroke volume increases. Exercise can also improve cholesterol and blood pressure levels, which are factors that contribute to heart health. It is suggested that individuals engage in 150 minutes of moderate exercise each week. This has been linked to increased heart health. Moderate exercise is defined as activity that increases your heart rate and makes it hard to talk during the activity. In contrast, vigorous exercise involves a heart rate above 130 or 140 beats per minute. When you engage in vigorous exercise, you will usually be unable to talk. The goal is to reach a target heart rate when exercising. This target heart rate for each individual is based on age. To calculate this, subtract your current age from 220 to get your target heart rate.

The Heart of Inquiry

The heart of this unit is engaging students in inquiry and experimentation. As a part of this, I want to build on what students do and do not know. Questioning is one of the major tools I want to use to get my students thinking. The willingness to question at the elementary level remains viable, and most of my students are open to it. Knowing this, I want to build on their willingness and help them understand that questioning is one way scientists learn more about the natural world.

Firestein asserts that questioning is one of the best tools science can use because science relies less on facts and more on inquiry. Scientists recognize that science is always changing; data can change, and our interpretation of data can change as well. More often than not, the quest for facts in science often leads to more of the unknown. I want students to embrace this as a way to continue exploration and extend their knowledge throughout this unit[30].

Berger asserts that people are innately born curious and possess the ability to question. He describes very young children as some of the best at questioning because they want to make sense of the world around them. For this reason, young children are some of our best scientists. However, as children get older, their willingness to question seems to lessen. In addition, Berger asserts that willingness to question and

engagement are highly correlated. Berger posits one reason may be standards-based education. Standards-based education tends to inundate teachers with a large number of objectives to teach in a short period of time. Many districts have started using scripted curricula that stifle teachers' creativity and, in turn, students' creativity. It becomes a vicious cycle[31].

This unit is designed to push students to question, think critically, and explore. Critical thinking requires students to think objectively and consider multiple viewpoints. As a hallmark of this lesson, students will be pushed to think critically about how exercise affects heart health in general and to consider the implications of their learning for different communities. I want this exploration to push students beyond their own beliefs and to draw conclusions using evidence[32].

The Heart of Teaching

5E Model

One instructional model I plan to use is the 5E model. In recent years, my district has adopted this instructional model to teach science at every grade level. This methodology has been utilized because the district recognized the need for students to be instructed using an inquiry-based model in which they would be actively engaged and have the opportunity to truly “do science”. Before this, there was a reliance on memorizing facts and teaching that focused on using worksheets.

The 5E Model involves 5 basic components: engage, explore, explain, elaborate, and evaluate.

This approach to science starts with a phenomenon and allows students to ask questions and conduct explorations to find answers to some of their questions. The teacher brings in scientific conclusions and “facts” later in the unit. The belief is that this progression gives students meaningful experiences to align with their conclusions and the teacher-provided information[33].

The engagement part of the lesson allows the teacher to provide a hook, ignite students' interest, understand their misconceptions, and get them thinking. The explore phase gives students a cooperative learning experience in which they begin to investigate some of the phenomena they explored. During this phase, teachers are not lecturing or providing direct instruction. Instead, the teacher serves as a facilitator of learning. The explain stage allows students to communicate some of the conclusions they have reached during the explore stage. This is when the teacher pulls in concrete notes and/or scientific information to provide formal explanations. The students can also engage in their own independent or cooperative research during this phase. During the elaborate phase, students can engage in more activities to test and, if possible, disseminate what they have learned. The final phase includes an evaluation. This type of evaluation does not have to be standardized. It can include a product, an open-ended assignment, and/or self- and/or peer assessment. It is important to note that this is a cycle and does not usually occur in a day. This model can happen over the course of several days or even weeks. Teachers may find they go back and forth between exploration and explanation before reaching elaboration and evaluation[34].

Cognitively Guided Math Instruction

Cognitively guided math instruction is the overarching instructional strategy used by all math interventionists

in my district. As a collective group, we read *Children's Mathematics: Cognitively Guided Instruction*. This book study helped us understand how students approach math and what it says about whether their understanding is still concrete or more abstract. The book also explores how students think mathematically at different developmental levels. The book also outlines strategies that teachers can use to advance students' mathematical reasoning. Cognitively guided math instruction encourages teachers to embrace student-generated solutions to math problems that may not align with traditional methods. In this way, teachers can understand where students are in their mathematical development, and students feel their knowledge is valued. There is also a strong emphasis in this book on pushing students to make their thinking visual and on using questioning to get and keep them thinking when teaching math[35].

The Math Behind the Beat

Heart Rate Detectives at Work

Solving the Case

Evidence from the Investigation

The Final Diagnosis

Appendix A

Math

5.CE.3 The student will estimate, represent, solve, and justify solutions to single-step and multistep problems, including those in context, using addition, subtraction, multiplication, and division with decimal numbers.

5.CE.4 The student will simplify numerical expressions with whole numbers using the order of operations.

5.PS.1 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 plots (dot plots) and stem-and-leaf plots.

5.PS.2 The student will solve contextual problems using measures of center and the range.

Science

5.1 The student will demonstrate an understanding of scientific and engineering practices by

- a. asking questions and defining problems
- b. planning and carrying out investigations
- c. interpreting, analyzing, and evaluating data
- d. constructing and critiquing conclusions and explanations
- e. developing and using models
- f. obtaining, evaluating, and communicating information

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