Mathematics and the Founding Fathers

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Although the Founding Fathers are best known for their political achievements, they were men of broad intellectual interests, including mathematics. The eighteenth century was the century of the Enlightenment, and they were profoundly affected by Enlightenment thinkers, especially John Locke. It is no exaggeration to say that Locke was the intellectual father of the Founding Fathers. Locke was acquainted with Isaac Newton, and he understood what Newton had accomplished by applying reason to the study of nature. His fundamental goal was to do the same for all questions, whether scientific or humanistic. Two of the founders who were deeply impressed by the Lockean approach were Benjamin Franklin and Thomas Jefferson.

Benjamin Franklin is generally not remembered for making contributions to mathematics, and he even lamented his lack of mathematical knowledge. Nevertheless, although he did not develop sophisticated mathematical techniques, he thought in symbolic and quantitative terms. For example, he taught himself Latin, Spanish, Italian, French, and German, he proposed daylight savings time, he charted the gulf stream, he was good at thinking in terms of numerical patterns, and he used matrices to organize information.

To illustrate Franklin's ability to extend the use of mathematics into new areas of inquiry, let us begin by examining his work in demography. By analyzing the growth of the population of the colonies, he concluded that it was exponential, and he measured it in terms of doubling time. He also recognized that there are factors inhibiting population growth, such as food supply and disease, which we know today as the logistic law. His work influenced the British economist, Thomas Malthus, who accepted Franklin's theory that population grows exponentially. Malthus also claimed that the food supply would grow only arithmetically, and that the result would be mass starvation, a claim Franklin never made. Franklin applied his knowledge of demography to the dispute between the colonies and Great Britain by noting that the population of the colonies was doubling every twenty to twenty-five years and would eventually overtake that of England, at which time the mother country would be governed by an American parliament and would be subject to taxation without representation.

Another area to which Franklin applied mathematical analysis is utility theory, which is concerned with devising measures of relative satisfaction. As a young man he made a list of thirteen moral virtues that he hoped to emulate, and at the end of each day, he gave himself a score on how well he had done. He referred to this process as his moral algebra. Later he extended his approach to decision making in general. He would list the factors supporting and opposing a decision, assign weights to the factors, total the results, and make his decision based on the outcome. Today utility analysis has a wide variety of applications in areas such as portfolio

theory, where it plays a fundamental role in the design of investment portfolios. In economics, it is used to calculate maximum utility and marginal utility, which is the additional satisfaction obtained by consuming one more unit of a product. As in the case of demography, Franklin did not contribute new, sophisticated mathematical methods to utility theory; rather, his achievement was to introduce mathematics into an area that not previously been quantified.

Benjamin Franklin was always a very curious person, and he was interested in improving the human condition. Some of his inventions include the Franklin stove, an odometer, the glass armonica, and bifocals. Franklin is probably best known, however, as a statesman and as a scientist for his work with electricity. He actually heard his first lecture on the subject when he was visiting Boston in 1743. By that time he had moved to Philadelphia and had become a successful businessman, and he had time to pursue other interests. When he first started investigating the subject, very little was known about the nature of electricity. His work, including the famous kite flying example, was experimental in nature and led to his invention of the lightning rod, a true life saver at the time. Although his contributions were not primarily mathematical, he formulated the principle of conservation of charge, which has been equated in importance to Newton's law of conservation of momentum. He introduced such terms as positive, negative, battery, conductor, condenser, charge, discharge, uncharged, electric shock, and electrician, and his work helped to provide the basis for mathematizing the field. One of his biographers observed that when he began to study electricity, it was a curiosity; when he finished, it was a science.

Franklin's work in electricity extended from the 1740s until the 1770s. As he became more involved with the political conflict with Great Britain, he had less time to devote to his scientific pursuits. However, he did not begrudge this state of affairs. Indeed, he noted that Newton himself would have been at fault if he had not seized the opportunity to establish a new nation. There is no question that Franklin answered the call of his country, for he is the only one of our founders who signed four very important documents in our history: the Declaration of Independence in 1776, the Treaty of Alliance with France in 1778, in which France agreed to join with the United States in the American Revolution, the Treaty of Paris in 1783, in which Great Britain recognized American independence, and the United States Constitution in 1787.

Unlike Franklin, who had only two years of formal schooling, Thomas Jefferson had the opportunity to pursue higher education. He attended the College of William and Mary in Williamsburg, Virginia, where he studied with a man named William Small, who was an advocate of the Enlightenment. Small introduced Jefferson to the work of such men as Newton and Locke, and he had a profound impact on the course of Jefferson's life. When Jefferson was contemplating his choice of a career, Small encouraged him to study law and introduced him to George Wythe, a prominent Williamsburg lawyer. Jefferson and Wythe soon realized that they had a number of common interests. Like Franklin, Jefferson had a strong affinity for languages, and Wythe at the time was considered to be the leading Greek scholar in Virginia. To prepare to for a legal career, Jefferson read law with Wythe for five years, and the two remained friends for the rest of Wythe's life.

Jefferson always said that mathematics was his favorite subject, and he considered the study of it to be essential preparation for a career in law. During the forty years when he almost continually held a wide variety of public offices, including state legislator, governor of Virginia, ambassador to France, the first secretary of state, the second vice president, and the third president, he applied mathematics to a number of issues he encountered. One of these was the apportionment of members of the House of Representatives. The Constitution specified an initial apportionment and required that a census be conducted every ten years to determine future apportionments. The first census was completed in 1790, and in 1791, Congress passed an apportionment bill based on a method suggested by Alexander Hamilton, the first secretary of the treasury and a protégé of George Washington.

Jefferson, however, objected to the legislation on two grounds. The Constitution requires that each member of the House represent at least thirty thousand constituents. While the bill met this stipulation on the national level, it failed to do so on the state level. Also, the method of apportionment was not specified in the bill. Jefferson said that the next apportionment might use another method, and there would be no consistency. He presented his objections to Washington so cogently that Washington vetoed the legislation, thereby casting the first presidential veto in American history. Jefferson then proposed an alternative method of apportionment, which was adopted and remained in effect until the census of 1840.

As secretary of state, Jefferson also placed our financial system on a decimal basis. At first glance this issue would seem to have been the responsibility of Alexander Hamilton, the secretary of the treasury. Hamilton, however, understood Jefferson's extensive knowledge of mathematics and yielded to him on the question. This is particularly significant because Jefferson and Hamilton were antagonists in so many respects. During his tenure as ambassador to France during the 1780s, Jefferson read a book by Simon Stevin, a sixteenth century Belgium mathematician, which advocated the adoption of the decimal system. In Stevin's time, both the decimal and Babylonian sexagesimal system were used in Europe. Jefferson was so impressed by Stevin's work that he became a proponent of the decimal system. He also suggested the terms, dime and cent, for tenths and hundredths.

Another issue that concerned Jefferson during his term as secretary of state was the confidentiality of diplomatic correspondence. Several systems were in use at the time, but he was not satisfied with any of them. After studying the problem, he invented a device called the Jefferson wheel cipher, which consisted of a sequence of wooden disks with the letters of the alphabet embedded on each one in random order. Of course, a total of twenty-six factorial disks is possible, and Jefferson built a wheel cipher consisting of thirty-six disks. By numbering the disks and arranging them in some sequence, one could encode a message. The recipient of the message would arrange his disks in the same order and decode the message.

Little is known about the use of the wheel cipher during Jefferson's time, and this was probably deliberate in order to maintain maximum security. However, a version of it was reinvented in France in the late nineteenth century, apparently without knowledge of Jefferson's work. A few years later, some information about the original wheel cipher was found in Jefferson's papers at the Library of Congress.

The leading American cryptanalyst at the time examined these documents and expressed amazement at the sophistication of Jefferson's approach. The United States military became interested in the wheel cipher and used it into the World War Two period.

One of Jefferson's avocations was architecture. He designed four buildings that can be visited today. The first is the statehouse in Richmond, Virginia, the second is his own home, Monticello (the name is Italian for Little Mountain), in Charlottesville, Virginia, the third is his weekend retreat, Popular Forest, in Lynchburg, Virginia, and the fourth is the rotunda at the University of Virginia in Charlottesville. He taught himself architecture by studying the work of the Italian architect, Andrea Palladio, and he incorporated many of Palladio's designs into his own work. The octagon was one of Jefferson favorite architectural shapes because he thought that it made very efficient use of space. One of the bedrooms at Monticello is octagonal, and when he designed and built Poplar Forest, he used this shape throughout the structure. The house as a whole is octagonal, and the floor plan consists of a central dining room in the shape of a twenty foot cube with four rooms branching from it. The spherical dome of the rotunda is inscribed in a cylinder, a shape reminiscent of Archimedes' favorite theorem, namely that if a sphere is inscribed in a cylinder of equal diameter, then the surface area and volume of the sphere are two thirds of those of the cylinder. Entry to the parlor at Monticello is by means of by a pair of glass doors that open simultaneously as a result of a chain in the shape of a lemniscate located beneath the floor. Although this device was installed when Jefferson built the home, it was not discovered until the house was renovated in the early twentieth century. Jefferson entertained numerous visitors at Monticello during his lifetime, and many were impressed with the beauty of his home. In particular, one French diplomat noted that Thomas Jefferson was the only man in America who used the fine arts to protect himself from the weather.

Jefferson, like Franklin, was also an inventor. His most original contribution was the design of a new plow. While Jefferson was in France, he began to think about this problem when he observed the primitive plows then in use. He focused on the moldboard, the part of the plow that turns over the soil once it has been cut. He originally thought that the moldboard should be planar in shape. However, Robert Patterson, a professor of mathematics at the University of Pennsylvania, with whom Jefferson was in regular correspondence, observed that he was trying to construct a surface of least resistance and that it should be curvilinear, not planar. Patterson reminded Jefferson that Newton himself had addressed this problem and that it was discussed in a calculus text by a man named William Emerson. As a student at William and Mary, Jefferson had learned calculus from Emerson's book, and he immediately understood Patterson's point. He consulted Emerson's work and used it to invent his new moldboard. His success in designing an improved plow illustrates his thorough knowledge of calculus and his ability to apply it. It is one of the reasons that he is considered to be the most mathematically sophisticated of the Founding Fathers.

It is difficult to encapsulate Thomas Jefferson in a few words. The breadth and depth of his interests were extraordinary. There are two comments, however, one about Jefferson and one by him, that give us a glimpse into his personality. The same Frenchman who was so impressed by the architecture of Monticello made some additional observations after his visit there. He noted that from an early age,

Jefferson had placed his mind, like his house, on an elevated site from which to contemplate the universe. Upon his retirement following his second term as president, Jefferson said of himself that nature intended him for the tranquil pursuits of science by rendering them his greatest delight. By the term, science, he meant not only what we mean today, but all knowledge. Jefferson had a voracious mind, and he reveled in the acquisition of knowledge in every form. He has been called a Renaissance Man and the American Leonardo, in comparison with Leonardo da Vinci.

Benjamin Franklin was also a Renaissance Man. He was a successful author, printer, publisher, inventor, scientist and statesman, achievements that are remarkable in light of his lack of formal education. He was the fifteenth of seventeen children, and there simply were not funds for his education. As a young man, he was apprenticed to his brother James, a successful printer in Boston. Young Franklin quickly mastered this job and began his lifelong quest for knowledge. He soon left Boston and eventually settled in Philadelphia, where he was able to practice his trade and continue his mission to improve the human condition. He formed a group called the junto that met weekly to discuss topics of common intellectual interest, and he also had a hand in establishing the first lending library in America. Later he founded the American Philosophical Society, today a scholarly organization of international reputation, which promotes useful knowledge in the sciences and the humanities. All of the founding fathers of the United States were members, and Jefferson was president of the organization for many years. Franklin was always a proponent of education. He even stressed its importance for women, especially in accounting and other aspects of running a business. He was one of the founders of the University of Pennsylvania and later endowed Franklin College in Lancaster, Pennsylvania, today known as Franklin and Marshall College. He also left funds for use by the citizens of both Boston and Philadelphia, a bequest that citizens of both cities are still benefiting from today.

Jefferson also had an enduring interest in education. He often said that the future of the nation rested on an educated citizenry. As governor of Virginia, he reorganized the curriculum of William and Mary into five schools, one of philosophy, another of mathematics and science, a third of languages, a fourth of medicine, and a fifth of law. The medical school was the second of its kind in the country, preceded only by one at the University of Pennsylvania, and the law school was the first in the new nation. Jefferson appointed his friend and mentor, George Wythe, to be America's inaugural law professor. The structural changes Jefferson implemented at William and Mary had a significant impact on college curricula throughout the country. While ambassador to France, he was in regular communication with several college presidents in the United States. When Joseph Lagrange published his work, Analytical Mechanics, Jefferson immediately informed the president of Harvard of its importance and explained in detail what Lagrange had accomplished. He urged American colleges to adopt Lagrange's analytical approach to the teaching of calculus. As President, he established the military academy at West Point and stressed the need for rigorous mathematical training. When he founded the University of Virginia, he once again gave mathematics a prominent place in the curriculum.

Among the Founding Fathers, Franklin and Jefferson were the foremost proponents of mathematics and mathematics education, but others, such as George Washington

and John Adams, also recognized its importance. Washington was a surveyor by profession, and he understood the value of mathematics and of education in general. At a crucial moment in its history, he saved the current Washington and Lee University from bankruptcy by providing it with an endowment. John Adams received a classical education at Harvard, including the study of mathematics. Years later, while helping his son, John Quincy, prepare for entrance to Harvard, Adams lamented how much time had elapsed since he had had the opportunity to study calculus. In addition to the profound debt that we owe the Founders for the freedom we enjoy today, we should also recognize their impact on education in general and mathematics education in particular in the new nation.

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