Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1990 Volume VII: What Makes Airplanes Fly? History, Science and Applications ofAerodynamics

Mankind’s Fascination With Flight

Curriculum Unit 90.07.03
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I. Introduction

Ever since I was a small child I have been fascinated with the concept of flying—of flying as high as I could and as freely as the birds. I can vividly remember sitting by the seashore and watching the birds scavenging for their dinners—gliding, pitching right and left, soaring, diving, and especially, fighting over a choice appetizer in midair. For Christmas one year, I couldn't wait for the snow to melt and the weather to warm up a bit so that I could field test my bright red water-pressurized rocket. And who could forget those balsa-wood airplanes that would loop and glide both indoors and outside—the kind that cost twenty-nine cents. The memories go on and on with decal model airplanes, paper planes, box kites and remote-controlled planes, and as usual, the bigger the kid, the bigger the toy.

As the years have passed, I have become fascinated with air travel, flying to various cities and countries the world over. Having completed our initial seminar in aerodynamics, I have a greater understanding of airplane flight, a stronger reassurance of my personal safety, and a keen appreciation for the incredible research and genius of the early pioneers of aviation.

II. Overview

This year my curriculum unit will focus on the Wright brothers, Orville and Wilbur, and their significant contributions to society. In order to appreciate their creative genius, we shall first take a close look at their family genealogy, tracing their family tree back to their grandparents, who were hard-working farmers, carriage builders and religious people. We will follow these young tinkerers as they move through their childhood and into their teens, briefly describing their entrepreneurial business undertakings which eventually led to their profitable bicycle selling and repair business. In their early twenties we will watch these trial and error scientists research Lilienthal's gliding principles, study ornithology, and discuss the inventions and discoveries of leading aeronautical figures such as Da Vinci, Montgolfier, Cayley, Chanute, and Langley. We will read about their early failures, study their wind tunnel experiments, be dismayed when they realize that their redesigned work is fruitless due to Lilienthal's incorrect air pressure tables, become excited when they discover ailerons and elevators, watch them closely as they redesign their gliders for successful lateral balance and stabler control, and finally fly with them on December 17, 1903, in the first heavier-then-air flying machine piloted by Orville Wright.

III. Objectives, Goals and Strategies

My unit objectives are to present an overview of the early history of flight; to discuss, examine and appreciate the science and inspiration of flight; and to highlight the achievements of the Wright brothers beginning with their useful adventures, experimenting with gliders, and subsequently, flying into history. Other goals and objectives are to familiarize students with the terms and the mechanics of powered flight; to improve my students' achievement in reading for detail and comprehension skills; to test their critical thinking and inferential skills; and finally, to utilize the inspiration, the perseverance, the "hard-working, refusing to give up" ethic as a catalyst to spark the imaginations and the efforts of my reading and literature students.

My strategies for teaching this unit of flight will reflect a diversified literary approach, I will present the genealogical background for the Wright brothers in autobiographical and biographical novels, short stories, and selected readings for discussion. Scientific concepts of aerodynamics will be presented in lecture form for student-teacher discussions. Slide presentations will introduce significant contributors to the history of flight such as DaVinci, Montgolfier, Cayley, Lilienthal, Chanute, and Langley. Brainstorming, critical thinking and inferential skills will be interwoven throughout the unit and many lesson plans will reflect "hands-on" experiences.

IV. The Wrights

As children growing up in Ohio, heredity may have played an important role in giving them mechanical ability, the ability to think creatively, and the willpower to continue experimenting in spite of failure. Their maternal grandfather, John Koerner, immigrated from Germany in 1818 and settled in Union County, Indiana, where Koerner carriages became famous for their dependability and their sturdy construction. Their paternal grandfather was a farmer with strong religious sentiments which were passed along to their father, Milton Wright, who became a preacher, a college professor, a minister, and finally a bishop. Their mother, Susan Catherine, was a college student when she married their father.

It's difficult to explain how inventors and inventions come to be. "Perhaps it's a combination of an insatiable curiosity, excellent mechanical ability, and a strong desire to create a machine or a process that will make life easier, do a job better, or perform a feat considered impossible before the invention was made." [1] (See Appendix X.A.) The Wright brothers had these advantages: ancestors and relatives who had been inclined to invent things, and understanding, sympathetic parents who encouraged their independent thinking. Their brother Lorin had developed improvements on hay-baling equipment, and their mother had an uncanny ability to invent tools that would simplify her household chores.

In their young lives, Wilbur and Orville often worked together demonstrating their entrepreneurial inventiveness. When Wilbur was twelve and Orville was eight, they built a wagon for Carmody's Junk Yard reducing wheel friction, enabling the wagon to effectively haul ten times as much as before. In their early teens, Wilbur invented a folding machine for newspapers; Orville built a small printing press for his "Midget Newspaper" and handbill advertising business; and they collaborated effectively by developing two local newspapers *Westside News* and *Snapshots.* These small operations were forerunners to their bicycle selling and repair business which became so profitable that they were able to finance, research and build their flying machines.

V. History of Flight

There have been many individuals who have, through an advancement of some technical skill or through sheer inspiration, progressed the science of flight. For this discussion we will highlight the achievements of the men and their magnificent flying machines that Wilbur acknowledged in his letters to the Smithsonian Institute. Each of these men represents his own particular time, and each evokes the spirit and essence of the "magic" of flight.

As far back as the 1480's, Da Vinci had a curiosity and an eye for life and its complexity. Four hundred years before the Wright brothers, Leonardo had studied the flight of birds, the movements of air, and he had designed several flying machines. His drawings of birds include notes on lift, thrust, equilibrium, steering and stability. Though never to fly himself, nor to create a workable flying machine, Da Vinci sensed the science behind flight. He wrote, "A bird is an instrument working according to mathematical law, which instrument it is within the capacity of man to reproduce with all its movements but not with a corresponding degree of strength, though it is deficient only in the power of maintaining equilibrium." [2] Leonardo Da Vinci obviously felt that man could reproduce the mechanics of flight by imitating the birds. That he was wrong, and in fact constructed models that could never fly, misses the point. His inquisitive mind and probing spirit acted as a catalyst for others who would follow. That those who followed Da Vinci refined his ideas only serves to illustrate that invention is very often an evolutionary process.

Probably the first aerial voyage of any kind that man attempted successfully was in a balloon. In 1783, Monsieur Rozier and Marquis d'Arlandes, using the technology applied by two brothers, Joseph and Etienne

Montgolfier, set sail in a balloon for a very brief trip across Paris. The technology behind this balloon trip was based on Archimedes' principle (Greek mathematician and physicist, 285—212 B.C.) "that a body wholly or partially immersed in a fluid experiences an upthrust equal to the weight of the fluid displaced." As the weight of the air varies with the temperature, the height and relative humidity, the rising force of the balloon and consequently its lifting force, varies with the atmospheric conditions. The trip lasted twenty five minutes and covered a distance of five miles. "For the first time man had left the ground for an appreciable time. It took another 120 years to realize the first flight of a heavier-than-air-machine, the Wright Flyer I." [3]

In England, in the early 1800's, Sir George Cayley was laying the groundwork for modern aircraft. He was the first to recognize that future airplanes would be propelled by engines (explosion motors) and controlled by man. He foresaw that the wings, the lifting surfaces, should be separated from the engine propulsion system. His "late designs had rigid wings, rudder, and elevator to control the yaw and pitch axes, and often some mode of propulsion. It is no accident that Sir George Cayley is universally regarded as the founder of modern aviation. As Wilbur Wright said in 1909, 'About 100 years ago an Englishman, Sir George Cayley, carried the science to a point which it had never reached before and which it scarcely reached again during the last century.' " [4]

The Wright brothers considered Otto Lilienthal's hang glider research crucial to their experiments. His cambered wings, being curved on top, gave his gliders greatly increased lift. He achieved greater stability in his gliders by rolling his body from right to left. Had he not died as a result of one of his gliding experiments in 1896 (at the age of 48), and had powered-engines reached a stage of greater horsepower and better reliability, it is not inconceivable that Lilienthal may have enjoyed center stage in the Smithsonian rather than the Wright brothers.

Another great influence upon the Wrights was Octave Chanute. Chanute, a successful engineer, was very interested in gliders and powered flight. His knowledge of previous aerodynamic experiments and his encouragement acted as a strong motivator to Orville and Wilbur. His text *Progress in Flying Machines* in 1894 contained progressive biplane designs that influenced the Wright brothers' work significantly. Shortly thereafter, letters of correspondence were exchanged and Chanute became a close friend and confidante. It was as a result of these letters that Kitty Hawk, North Carolina was chosen to conduct experiments with a man-carrying glider, a suggestion made by Octave Chanute.

Finally, Samuel Langley's accomplishments caught the attention of the Wright brothers. In 1896, the Langley Aerodrome Model No. 5 demonstrated the possibility of flight. This model was powered by a small steam engine. This unmanned model made the first significant flight of any engine-driven, heavier-than-air craft. Professor Langley's later attempts at manned flight in a full-sized version of the Aerodrome were unsuccessful. Also launched from a houseboat anchored in the Potomac, the larger craft hit the water almost immediately after launch in October, 1903. A second attempt on December 8th ended in similar fashion.

By 1899, the Wrights' interest in flying had peaked. They sought out everything that had been written on the subject. After reading a text on ornithology, they decided to try gliding themselves. "We could not understand that there was anything about a bird that would enable it to fly that could not be built on a larger scale and used by man. At this time our thought pertained more particularly to gliding flight and soaring. If the bird's wings could sustain it in the air without the use of any muscular effort, we did not see why man could not be sustained by the same means." [5] The Wrights reasoned that the failure of early experimenters was due primarily to their inability to properly balance their gliders in flight. "The period from 1889 to 1897 we found had been one of exceptional activity, during which Langley, Lilienthal, Chanute, Maxim and Phillips had been feverishly at work, each hoping to win the honor of having solved the problem; but one by one they had been compelled to confess themselves beaten, and had discontinued their efforts. In studying their failures we found many points of interest to us." [6]

VI. The Wrights' Aerodynamic Research

After considerable correspondence with the Smithsonian Museum and reading numerous works on the subject of aerial navigation, the Wrights were very much impressed with the great number of people who had given serious thought to the notion of flying. It was Chanute's encouragement that prodded the Wrights into continuing their experiments when lesser men may have given up in frustration or despair. In a letter to Chanute in May, 1900, Wilbur suggests his belief that "flight is possible to man." [7] His observations of the flights of buzzards and other birds convinced him that knowledge and skill were of greater value than machinery. "My observation of the flight of the buzzards leaves me to believe that they regain their lateral balance when partly overturned by a gust of wind, by a torsion of the tips of the wings." [8] A year earlier, Wilbur had made this discovery quite by accident. While he was working in the bicycle shop in Dayton, Ohio, a customer had dropped in to make a tire purchase. While talking to the customer, Wilbur was toying with the pasteboard box that the tube came in, and he noticed that as he twisted the box, the vertical sides were rigid endwise though the top and bottom sides could be twisted to have different angles at the opposite ends. Why then couldn't the wings of a gliding machine be warped from one end to the other in a similar fashion; that is, the technique of a helical twisting of the wings, "the Wrights' 'basic idea was the adjustment of the wings to the right and left sides to different angles so as to secure different lifts on the opposite wings'." [9] This wing warping technique was of crucial significance in order to assure lateral control about the roll axis. "One of the prime elements in the success of the Wright brothers at Kitty Hawk was their control of the airplane about all three axes of flight." [10] The roll of the plane was controlled by *wing warping;* the pitch of the plane was controlled by the *forward elevator;* and the yaw of the plane was controlled by a movable rear rudder. In the early years, these control functions were combined but in later aircraft, each functioned independently.

VI.A. Scientific Kite Flying

Shortly thereafter, the two brothers constructed a biplane kite which had two wings measuring 5 feet from tip to tip and 13 inches wide, mounted one above the other. They connected cords attached to sticks to be manipulated by the operator to the corners of the wing tips. With a stick in each hand, the operator could cause the wing surfaces to be exposed to the wind at varying angles, increasing or decreasing the wing's lift and controlling the movement at the center of pressure. In addition to the wing warping, the Wrights also added a fixed rear elevator which helped to turn the kite in the same direction that the wings were turning—thus helping to stabilize the kite. "According to Wilbur's account of the tests, the model worked very successfully. It responded promptly to the warping of the surfaces, always lifting the wing that had the larger angle . . . .. We felt that the model had demonstrated the efficiency of our system of control." [11]
(Illustration—See Appendix X.E.1)

VI.B. First Glider—1900

Due to their successful kite-flying experiments in 1899, the Wrights decided to build a man-carrying glider in August 1900. They determined that they would need flat, open country free of trees and shrubs, with suitable wind conditions. Chanute suggested locations in California and Florida but also areas in the Carolinas. The United States Weather Bureau suggested Kitty Hawk, North Carolina. Given the proximity to Dayton, Ohio and the friendly, knowledgeable replies from J. Dosher (Chief of the Kitty Hawk weather bureau) and W. Tate (Postmaster of Kitty Hawk), the Wrights decided on Kitty Hawk as the place for their experiment, sight unseen.

Throughout the summer, the brothers assembled their first man-carrying glider at the cost of $15.00. It weighed about 52 pounds, had a total span of 17 1/2 feet, a lifting area of 165 square feet, an 18 inch wide area in the center of the lower wing for the operator, and the spars were made of ash covered with white French satin and connected with metal screws. The wing curvature was less than what Lilienthal had used and the glider was to be flown initially as a kite. However, as September and October passed, the Wrights spent much of their time flying the glider *as a kite* . Some of their problems were the uneven wind conditions at Kitty Hawk: the winds of 17—21 miles per hour were not adequate to support both pilot and plane, their questioning of the accurate validity of Lilienthal's air pressure tables, the amount of curvature on their wings, and the density of their French satin to cover their wings. While gliding at Kill Devil Hill (4 miles south of Kitty Hawk), their control of the machine was better than expected. The machine exhibited quick response to the front elevator which promised to be satisfactory in maintaining fore and aft balance around the pitch axis. Lateral balance was obtained by their wing warping techniques around the roll axis. By October 23, 1900, the Wrights had flown their machine ten minutes with a man aboard as a kite and two minutes as a glider. "Though the amount of practice was less than they expected, all the Wrights had learned in that season of 1900 seemed to confirm the correctness of certain opinions held at the beginning. Their method of warping or twisting the wings to maintain lateral balance was better than dependence on either the dihedral angle or shifting the weight of the operator; better than any method yet tried. And their front elevator had been highly satisfactory as a means of directing the machine up and down." [12] (Illustration—See Appendix X.E.2)

VI.C. Second Glider—1901

During the winter of 1900-1901, the Wrights set to work on a larger glider, one large enough to be flown as a kite, with an operator aboard, in the kinds of winds that they could expect. They decided to make it of the same general design as the first one and with the same system of control. They increased the curvature of the wings to conform to the shape on which Lilienthal had based his table of air pressures and the total lifting area was 290 square feet as compared with 165 square feet in the previous glider. The air pressure tables were of critical importance because they provided the directions for computing lift, drag and the resultant pressures. The machine weighed nearly 98 pounds, nearly double the first one. The front elevator had a 4 1/2 foot chord and an area of 18 square feet. The wings had a total span of 22 feet with 7 foot chords and a section of 20 inches was removed from the middle of the lower wing for the operator. This was a much larger plane than anyone had ever tried to fly. The new plane was completed and ready to fly on July 27, 1901. Since it was designed to fly into winds of 17 miles per hour at an angle incidence of 3°, the trial was moved to Kill Devil Hill for stronger wind conditions. Although several glides on that afternoon exceeded the best of the year before, it was evident that this machine was not as good as the previous one. It could not glide on a slope nearly as level as the earlier machine. As used by the Wrights, the gliding angle was the angle between the horizon and the relative wind or the angle between the horizon and the angle of descent. The fore and aft balance was more difficult to control due to the wing camber of 1 to 22. Camber is the rise of the curve of an airfoil from its chord; a wing camber of 1 to 22 is the ratio of the maximum distance of this curve from the chord in proportion to the length of the chord. When they reduced this to a camber of 1 to 19, the control of the machine appeared to be as good as the year before.

The results of the 1901 trials demonstrated that all records for gliding distance had been broken; that the machine was strong; that the larger glider could be controlled almost as easily as the smaller one, provided that the control was by a manipulation of the surfaces themselves rather than by the movements of the operator's body; and that the lateral balance of the machine seemed to be all that could be desired. However, the Wrights were far from being satisfied in that they based all their calculations on wing size, camber, and the angle of incidence on incorrect tables. "On the way home, Wilbur declared his belief: 'Not within a thousand years would man ever fly.' "[13] (Illustration—See Appendix X.E.3)

VI.D. Wind Tunnel Experiments—1901

After Wilbur suggested that Lilienthal's air pressure tables contained incorrect data at a speech given in Chicago to the Western Society of Engineers, Orville contrived a little wind tunnel made of an old starch box to make a series of tests. He felt that his results were conclusive enough to support Wilbur's position in his criticism of those scientific works. Later, they would find out that the published errors were greatest in regards to small angles—the ones that would be used in flying, and that he had only tested larger angles. Soon afterwards, the Wrights built a much better wind tunnel. It was an open-ended wooden box, 16 inches square by 6 feet long. The air was driven in one end by a gasoline engine attached to a fan by a series of small pigeonholes which created an even air flow. During the months of October and November of 1901, the Wrights tested more than two hundred types of miniature wing surfaces. They used monoplane, biplane, and triplane models. They measured the lift produced by different *aspect ratios* (the ratio of the span of the wing to its chord). Among other things, the experiments showed the inefficiency of deeply cambered wings and the fallacy of the sharp edge at the front of the airplane wings. "As the experiments continued, they marked a turning point in the efforts of man to fly for they gave knowledge no one had ever had before of how to design wings efficient enough to make possible a flying machine. It is the design of these wings rather than the engine or propellers that enable a plane to lift itself into the air." 14 (Illustration—See Appendix X.E.4)

VI.E. Third Glider—1902

On August 25, 1902, the Wright Brothers set out to Kitty Hawk, North Carolina once again. By September 8, they had assembled their new glider and on September 19, they were ready to renew their "on site" experimentations. The *wing span* had been increased from 22 to 32 feet; the *total span* was six times the chord instead of three as a result of the aspect ratio discovery determined in the wind tunnel experiments; the *wing warping* now worked by the sideways movement of the pilot's hips resting on a cradle instead of by movement of the operator's feet; and the *addition of a tail* consisting of fixed, twin vertical veins designed to offset the difference in resistance of the wing tips when the wing was turned into the wind at a greater angle were among the new improvements for the 1902 glider.

During the months of September and October, they made over 1,000 glides, several of them more than 600 feet, usually against winds greater than 30 miles per hour. The Wrights felt that this machine was twice as efficient as any other glider ever built. However, every once in a while, the plane would turn sideways and come sliding to the ground despite all the wing warping the pilot could exert. They determined that the tailspins were being caused by the addition of the new fixed rudder. Orville, lying awake in bed one night, reasoned that when the machine tilted laterally it began to slide sideways while moving forward—thus the speed increasing. Should the operator fail to balance the plane quickly enough, the wind hit the vertical rudders on the low wing instead of the sides towards the high wing, thereby assisting in the turning movement rather than counterbalancing the plane. In this case, the result would have been better had there been no fixed vertical rudder at all. Therefore, they decided to make the vertical tail movable, to permit the operator to bring pressure to bear on the side toward the higher wing. This system of control is widely used today—the independent control of aileron and rudder. In addition, Wilbur suggested combining the functions of the mechanisms that control the wing warping with that which moved the tail. Then the pilot would need only to maneuver the front elevator and the wing warping device. They also changed the tail from two vertical fins to a single vertical rudder. Having stabilized their gliders in flight, the brothers believed that now they could build a successful power-flyer. (Illustration—See Appendix X.E.5)

VII. Powered Flight Research: 1902-1903

After inquiring to automobile and gasoline motor manufacturers for supplying an *eight horsepower motor* not weighing more than 200 pounds, the Wright brothers decided to build their own. Together with their chief mechanic, Charlie Taylor, they built a sixteen horsepower motor which reduced to twelve horsepower in flight, weighing 170 pounds. The additional horsepower allowed them to add 150 pounds of materials to strengthen their machine. The wings had a total span of forty feet and the upper and lower surfaces were six feet apart.

The engine was placed on the lower wing just right of center to offset the weight of the operator just left of center. To guard against the plane rolling over upon landing, sled-like runners extended four feet in front of the main surfaces of the plane. The tail of the machine had twin movable rudders.

The Wrights left the designing of propellers until last because they felt sure that their tables of air pressures derived from their wind tunnel experiments would enable them to calculate the exact thrust necessary to sustain the machine in flight. The more they studied the problem, the more complex it became. They reasoned that the thrust depends upon the speed and the angle at which the blade strikes the air.

After many months of analyzing the intricacies involved in the action of screw propellers, the Wrights felt they were sure of their ability to design propellers with the exact diameter, pitch and area for their needs. "We have been unable to find anything of value in any of the works to which we had access, so that we worked out a theory of our own on the subject, and soon discovered, as we usually do, that all the propellers built heretofore are *all wrong,* and then built a pair of propellers 8 1/8 feet in diameter, based on our theory, which are *all right!* (till we have a chance to test them down at Kitty Hawk and find out differently). Isn't it astonishing that all of these secrets have been preserved for so many years just so that we could discover them!" [15]

VIII. Powered Flight—1903

After months of intensive, exhaustive research and experimentation, the Wrights set out for Kitty Hawk on September 23, 1903. Three weeks were needed for assembling the new machine. From time to time, they flew the 1902 glider, each brother establishing new world records by gliding over a minute. They had hoped to have their power machine ready for its first flight early in November but when they started their motor on the completed machine, an unexpected backfire produced a strain on one of the propeller shafts and tore loose the cross-arm to which the propeller was fastened. Both pieces had to be sent back to be repaired and strengthened in Dayton. On November 20, the shafts made of larger and heavier tubing arrived and were promptly assembled. But a new problem appeared. When both propellers were on, the shock greatly increased on each other. The sprockets, which were screwed to the shaft and locked with nuts, kept coming loose. Being bicycle shop repairmen they successfully solved this newest problem. "The next morning, thanks to Arnstein's hard cement, which will fix anything from a stop watch to a thrashing machine, we stuck those sprockets so tight I doubt whether they will ever come loose again." [16]

Once again the Wrights were poised to test fly their powered machine but inclement weather postponed their attempts for several days. During that time, they developed mechanisms to automatically measure the distance through the air (anemometer), the duration of the flight (stopwatch), and the number of revolutions made by the motor and the propeller (a counter on the engine). They also tested the wing strengths as well as the engine. It was during one of these engine tests on November 28 that they discovered a crack in one of the recently repaired tubular shafts; subsequently, Orville returned to Dayton immediately to replace the shaft with solid tool steel as winter was closing in on them rapidly. On Friday, December 11, Orville was back in camp and by the next afternoon, the machine was ready for trial again. But due to uncooperating weather, the trial was postponed again until Monday. That morning, the weather was clear and cold but there was not enough wind to start from level ground near the camp. Therefore, they decided to attempt the flight from the side of Kill Devil Hill. Wilbur won the coin toss, and, in front of five witnesses from the Kill Devil Life-Saving Station (John T. Daniels, Robert Westcott, Thomas Bechom, W. S. Dough, and "Uncle Benny" O'Neal), achieved partial success. He was airborne for 3 1/2 seconds, climbed a few feet, stalled, and landed near the foot of the hill. Although he only flew 112 feet landing many feet below the starting point, the experiment had demonstrated that their launch method was a safe and practical one. Overall, they were very much pleased.

The next two days were spent in making repairs, and on Thursday, December 17, 1903, the Wright Brothers secured their place in aviation history as they piloted the first heavier-than-air flying machine. In the words of Orville Wright, let us recall that glorious day . . .

"When we got up, a wind of between 20 and 25 miles was blowing from the north. We got the machine out early and put out the signal for the men at the station. Before we were quite ready, John T. Daniels, W. S. Dough, A. D. Etheridge, W. C. Brinkley of Manteo, and Johnny Moore of Nag's Head arrived. After running the engine and propellers a few minutes to get them in working order, I got on the machine at 10:35 for the first trial. The wind according to our anemometer at this time was blowing a little over 20 miles (corrected) 27 miles according to the Government anemometer at Kitty Hawk. On slipping the rope the machine started off increasing in speed to probably 7 or 8 miles. The machine lifted from the truck just as it was entering on the fourth rail. Mr. Daniels took a picture just as it left the trucks.

> I found the control of the front rudder quite difficult on account of its being balanced too near the center and thus had a tendency to turn itself when started so that the rudder was turned too far to one side and then too far on the other. As a result, the machine would rise suddenly to 10 feet and then as suddenly, on turning the rudder, dart for the ground. A sudden dart when out about 100 feet from the end of the track ended the flight. Time about 12 seconds (not known exactly as watch was not promptly stopped). The flight lever for throwing off the engine was broken, and the skid under the rudder cracked.
>
> After repairs, at 20 minutes after 11:00 Will made the second trial. The course was about like mine, up and down but a little longer . . . over the ground though about the same in time. Distance not measured but about 175 feet. Wind speed not quite so strong.
>
> With the aid of the station men present, we picked the machine up and carried it back to the starting ways. At about 20 minutes till 12 o'clock I made the third trial. When out about the same distance as Will's, I met with a strong gust from the left which raised the left wing and sidled the machine off to the right in a lively manner, I immediately turned the rudder to bring the machine down and then worked the end control. Much to our surprise, on reaching the ground the left wing struck first, showing the lateral control of this machine much more effective than on any of our former ones. At the time of its sidling it had raised to a height of probably 12 to 14 feet.

At just 12 o'clock Will started on the fourth and last trip. The machine started off with its ups and downs as it had before, but by the time he had gone three or four hundred feet he had it under much better control, and was traveling on a fairly even course. It proceeded in this manner till it reached a small hummock out about 800 feet from the starting ways, when it began its pitching again and suddenly darted into the ground. The front rudder frame was badly broken up, but the main frame suffered none at all. The distance over the ground was 852 feet in 59 seconds." [17] (Illustration—See Appendix X.E.6) It was unlikely that any of the five spectators (J. T. Daniels, W. S. Dough, A. D. Etheridge, W. C. Brinkley and Johnny Moore) who witnessed these flights sensed their scientific importance. Even the Wright brothers were not excited because they had only done what they sought out to accomplish. Soon afterwards Orville sent a telegram to their father informing him of their four successful flights, asking him to inform the press, and promising to be home by Christmas. Ironically, Frank Tunison (City Editor of the Dayton Journal) refused to print the event because he thought a flight of less than a minute was not newsworthy.

The Wright brothers were two creative geniuses who mastered the theory and the practical application of aviation. Their gliders and powered flying machines were of superior design and construction. Their methods and materials were thoroughly tested and retested. Their scientific data was constantly being reevaluated. They mastered the construction and utilization of propellers and engines. Their wind-tunnel experiments provided accurate measurements for lift which proved to be one of the great turning points of attempts at human flight. Their mastery of flight control with the discovery and implementation of ailerons, wing warping techniques, front elevators and flexible rear tails or rudders stabilized lateral and longitudinal balance. These and other achievements enabled the Wrights to be the first to fly.

Their technical achievement in 1903, given that their work was self-financed, that both men were self-taught mechanics, that neither had college or advanced training, and that their bicycle business occupied substantial time only serves to highlight their accomplishments. Two trial and error scientists with keen mechanical aptitudes and creative, analytical abilities were able to take their rightful place in history as “Conquerors of the Air.” Imagine!

IX. Lesson Plans

1. National Air and Space Museum Slides

As an introductory lesson to the Wright brothers and their quest for flight, slides taken at the National Air and Space Museum will serve to prepare the way for the Wright brothers and then to highlight their accomplishments.

2. Reading for details, comprehension, main ideas, inferential skills, and drawing conclusions

Students, utilizing Carroll Gline’s text *The Wright Brothers* will be encouraged to prepare chapter summaries each evening as they work through their assignments. Within the context of each chapter, the students will be challenged with a variety of reading skills while maintaining a chronological sequence of events and a unifying central focus, culminating with a comprehensive book report.

3. Wing Warping Experiment

To attempt to understand the discovery and the functioning of the Wright brothers system of lateral balance control, each student will be given a small box similar to the starch box with which Wilbur demonstrated to Orville the principles of wing warping. With the opposite ends removed, he held the top forward corner and the rear lower corner of one end of the box between his thumb and forefinger, and the rear upper corner and the lower forward corner of the other end the same way. By pressing the corners together, the upper and lower surfaces were given a spiral twist, presenting the top and bottom box surfaces at different angles on the right and left sides. Subsequently, the students will be able to apply this knowledge of twisting the wings to cause the wings to be exposed to the wind at varying angles which would in turn increase or decrease the lift under a wing and cause the kite to turn. When assembling the model of the 1903 Wright Flyer, the students will be able to understand these principles with practical applications.

4. Orville Wright’s Diary Excerpt from December 17, 1903

Having finished Gline's text *The Wright Brothers* individually, and having enjoyed the oral and chapter reading selections in class, students will have the opportunity to recall that glorious day in aviation history as Orville recounts that day in his own words . . .

5. The Wright Flyer

As a culminating activity, students will have the opportunity to work together, reading directions, assembling parts, and thereby creating a scale model of the 1903 Wright Flyer. Students will gain an appreciation for the skill and teamwork involved in building a machine from start to finish. During the process, students will be challenged to understand and to determine the Wright brothers' reasoning for the aerodynamic functioning of each of the machine's features.

X. Appendix

X. A. Footnotes

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1. Glines, C. *The Wright Brothers—Pioneers of Power Flight.* Watts 1968 . pg. 10.
2. Duke, N. and Lanchbery, E. *The Saga of Flight.* Day. 1961.
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X. B. Chronology

1867 April 16, Wilbur Wright born
1871 August 19, Orville Wright born
1892 Wright brothers open bicycle shop
1896 Begin glider experiments
1899 Construct glider with “warped wings”
1900 Construct man-carrying glider; begin experiments at Kitty Hawk, North Carolina; meet Octave Chanute, pioneer in aeronautics
1901 Experiment at Kitty Hawk with new, larger glider: realize air pressure tables are wrong; devise new tables; construct wind tunnel
1902 Experiment at Kitty Hawk with still larger glider; set number of world records in controllable glider
1903 December 17, both brothers successfully fly in powered machine; apply for U. S. patent
1904 Test flights with new plane near Dayton, Ohio; first use catapult; apply for foreign patents
1906 U. S. patent granted
1907 War Department establishes Aeronautical Division
1908 Brothers win Army bid to demonstrate flying machine and train pilots; May 14, take up first passenger; Wilbur goes to France to demonstrate plane, breaks many records; Orville demonstrates plane for Army; crash kills passenger
1909 Orville and sister join Wilbur in Europe; return home to finish Army tests; complete tests in Germany; Wright Company formed
1910 Orville begins flying schools near Montgomery, Alabama; and Dayton, Ohio.
1911 U. S. government votes for military aviation for the first time; establishes first military flying school, College Park, Maryland
1912 May 30, Wilbur dies at the age of forty-five
1915 Orville buys Wright Company outright
1916 Airplane makes mark in World War I; controversy begins between Wright and Smithsonian Institution
1918 Orville makes last flight as pilot
1923 Orville agrees to send original plane to London museum
1928 Original Flyer shipped to London
1948 January 30, Orville dies; December 17, Flyer returned to U. S. and Smithsonian Institution

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10. THE WRIGHT BROTHERS: 1899-1901

X.E.1. A. Wright biplane kite (shown without the tailplane-cum-elevator): 1899

(figure available in print form)

X.E.2. B. Wright No. 1 glider: 1900

(figure available in print form)

X.E.3. C. Wright No. 2 glider: 1901

(figure available in print form)

X.E.4. Plate 30. Balance for measuring lift of model aerofoils in the 1901 wind-tunnel experiments

(figure available in print form)

11. THE WRIGHT BROTHERS: 1902

X.E.5. A. Wright No. 3 glider (first form), with fixed fins: 1902

(figure available in print form)

B. Wright No. 3 glider (modified), with rudder, Wilbur piloting: 1902

(figure available in print form)

14. THE WRIGHT BROTHERS: 1903-04

X.E.6. A. Wright powered Flyer I, after the first—unsuccessful—test (Wilbur piloting):December 14th, 1903

(figure available in print form)

B. First flight of the Wright powered Flyer I (Orville piloting):December 17th, 1903

(figure available in print form)